# A GEOLOGICAL EVALUATION OF THE TECHNICAL FEASIBILITY OF LONGWALL MINING IN THE GALT SEAM AT KIPP TRIAL MINE NUMBER 1787/E/01 (UP-P-137)

## FINAL REPORT

by

PRECAMBRIAN SHIELD RESOURCES LIMITED

Work on this project was conducted under the auspices of the Canada Centre for Mineral and Energy Technology, Energy, Mines and Resources, Canada.

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# PICTURE BUTTE COAL PROJECT
# A TECHNICAL ASSESSMENT
OF
PICTURE BUTTE
1983

PREPARED FOR

PRECAMBRIAN SHIELD RESOURCES LIMITED

SUBMITTED BY

ASSOCIATED MINING CONSULTANTS LTD.

THE ASSOCIATION OF
PROFESSIONAL ENGINEERS,
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JUNE 1983

AR-64

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**Attention:** Mr. J.H.H. Chamberlin, P.Eng.
Vice President, Coal

Dear Sirs:

**Re: Picture Butte Coal Project**
**A Technical Assessment of Picture Butte - 1983**

We are pleased to submit our final report **'Picture Butte Coal Project - A Technical Assessment of Picture Butte - 1983'.** This study has enabled us to evaluate mining potential at Picture Butte with respect to additional geotechnical data acquired in 1983 since the presentation of our report AR-61B, dated January 1983.

Extrapolating the information gained at Kipp to Picture Butte we conclude that:

- Inseam physical characteristics and the behaviour of the coal and proximate roof and floor strata at Kipp indicate that with proper selection and application of today's coal mining technology, a longwall system of mining is possible at Picture Butte.
- The geologic correlation indicates that the roof and floor strata at Picture Butte will be similar to that encountered at Kipp. Indications from geotechnical data correlation are that ground conditions at Picture Butte will be similar to those encountered at Kipp during the TMP. Furthermore, it should be noted that actual ground conditions encountered at Kipp were better than those anticipated from geotechnical data collected prior to shaft sinking and mining.

.....Page 2

- The existence of any buried channels or major aquifers lying above the Galt Seam across the Picture Butte property is considered extremely unlikely.
- Hydrogeologic conditions within the Galt Seam at Picture Butte should be the same as at Kipp. Large quantities of groundwater flow through the Galt Seam at Picture Butte are, therefore, not anticipated.
- The low permeability of the overlying bedrock and glacial overburden should minimize any ground water inflow from the overburden into mine workings.
- Main entries required for the long term should be driven as small as practicable and supported by arches complemented by roof bolts where required. The preferred direction of main entry driveage is south to north or north to south - the "weak roof" direction.
- Service roadways for longwall retreat required for a short-term should be driven as narrow as possible, rectangular in shape, in an east to west or west to east direction - the "good roof" direction.
- When all relevant parameters to mine design are evaluated, it is possible that some areas of the Picture Butte property will not be capable of being mined using the longwall system. Alternate mining systems may have to be considered to maximize the recovery of coal resources in areas of thin rock overburden and irregular fault bounded blocks.

We hope this report meets your immediate requirements. If you have any questions regarding the contents of the report please do not hesitate to contact us.

Respectfully submitted,

**ASSOCIATED MINING CONSULTANTS LTD.**

Hans U. Bielenstein, P.Geol.
Senior Geologist

**GOLDER ASSOCIATES**

Ian T. Rozier, P.Eng.
Associate

HUB/ITR:ms

# PICTURE BUTTE COAL PROJECT
# A TECHNICAL ASSESSMENT OF PICTURE BUTTE
# 1983

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# PICTURE BUTTE COAL PROJECT
# A TECHNICAL ASSESSMENT OF PICTURE BUTTE
# 1983

## SUMMARY OF FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

The objectives of the TMP and the geotechnical studies at Kipp and Picture Butte were to determine the following parameters:

- Floor conditions such as: liability to heave; potential effects of water; load bearing capabilities for longwall roof supports and the identification of other potential problems related to floor strata.
- Roof control such as: stability of and optimum alignments for roadways and longwall faces; optimum horizon and width of roadway development; suitability of support systems; caving characteristics of superincumbent strata; and the identification of other potential roof control problems.
- Other objectives of the TMP were to detect the presence and amounts of any methane gas and water; and to identify other potential problems associated with the mining of the Galt Seam.

It is considered that this study has been successful in meeting these objectives and has provided data, as presented in our report of January 1983 and in this final report, which is directly applicable for input into mine design and feasibility studies for eventual development of underground mines at Picture Butte. Potential development of these and other underground mines at Lethbridge should be considerably enhanced by the technical knowledge acquired during the Picture Butte study, particularly in regard to conditions associated with roadway development, roof support and ground control in general, and the application of longwall mining techniques in particular.

Based upon data from the TMP and from the correlation of geotechnical data across the area, we conclude that the application of longwall mining of the Galt Seam should be technically feasible at Picture Butte.

In summary, the observations and data obtained from the TMP at Kipp Mine, together with correlation of geotechnical data from that area and the limited geotechnical data from the Picture Butte area indicate the following:

a. Inseam physical characteristics and behaviour of the coal and proximate roof and floor strata at Kipp indicate that with proper selection and application of today's coal mining technology, a **longwall system of mining is possible at Picture Butte.**

b. **Main entries** required for the long term should be driven as small as practicable and supported by arches complemented by roof bolts where required. The preferred direction of main entry driveage is south to north or north to south - the "weak roof" direction.

c. **Service roadways for longwall retreat** required for a short-term should be driven as narrow as possible, and rectangular in shape, in an east to west or west to east direction - the "good roof" direction. Roof bolts adjacent to the ribs of the retreat pillar of coal to be mined should be angled over the rib to help prevent roof fractures parallelling the rib line at or near the face, thereby reducing rock dilution of the coal.

d. **Service roadways for longwall advance** must be of the arch type, supported by rigid or yielding arches, these would also be driven in the "good roof" direction. Roadside packs of hardwood, anhydrite or aqua-packs can provide adequate roadway stability. If legislation permits, shearers capable of cutting roadway arch profiles could be used to drive these service roadways in line with the advance of the longwall face.

e. When all relevant parameters to mine design are evaluated, it is possible that some areas of the Picture Butte property will not be capable of being mined using the longwall system. Alternate mining systems may have to be considered to maximize the recovery of coal resources in areas of thin rock overburden and irregular fault bounded blocks.

# PICTURE BUTTE COAL PROJECT
# A TECHNICAL ASSESSMENT OF PICTURE BUTTE
## 1983

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1-1 Location Map

# SECTION 1 - INTRODUCTION

## 1.1 INTRODUCTION

Associated Mining Consultants Ltd. with Golder Associates were retained by Precambrian Shield Resources Limited (PSRL) to undertake a Geotechnical/Strata Control Trial Mining Program in the Galt Seam at Petro-Canada's Kipp Mine, implement the collection of geotechnical data at Picture Butte and provide preliminary mine design parameters for mining the Galt Seam at Picture Butte (Figure 1-1).

The terms of reference for this study are outlined in a joint proposal submitted to Precambrian Shield Resources Ltd. by AMCL and Golder Associates, dated March 1982, as amended in April, 1982 and again in September 1982. The basic objectives of the program were as follows:

- Evaluate available data from the Lethbridge area.
- Implement a geotechnical data collection program at Kipp Mine.
- Carry out a trial mining and monitoring program at Kipp to test relevant geotechnical/strata control features.
- Implement a geotechnical data collection program at Picture Butte integrated with PSRL's 1983 exploration drilling program.
- Evaluate the results of these studies and formulate preliminary mine design parameters applicable to mining at Picture Butte.

The Galt Seam has previously been exploited in the Lethbridge area, the last mine closing in 1964. A literature study was carried out to document recorded mining conditions in this coalfield for comparison with those anticipated by previous geotechnical studies by Dames and Moore and Golder Associates in the Lethbridge area. The evaluation of previously accumulated data assisted in determination of geotechnical/strata control parameters at Kipp. The intent of the TMP was to evaluate the potential for, and to determine appropriate mine design parameters applicable to longwall mining at Picture Butte.

The geotechnical/strata control project incorporated underground studies at the Kipp Mine and geologic/geotechnical investigations at Picture Butte. The project evolved so that the studies at Kipp took place during 1982, and the studies at Picture Butte during early 1983.

The first phase of the geotechnical/strata control project, the Trial Mining Program at Kipp, was completed in late 1982; a report entitled **'Picture Butte Coal Project - Trial Mining Program - Kipp'** (AR-61A) was prepared and submitted in early 1983.

Available geologic and geotechnical data was evaluated and a report prepared entitled **'Picture Butte Coal Project - A Technical Assessment of Picture Butte'** (AR-61B).

Subsequently a small exploration program of 6 drillholes was carried out by PSRL at Picture Butte in February/March, 1983. The 1983 geotechnical program was integrated with this exploration.

This report (AR-64) gives a re-assessment of the anticipated geotechnical/strata control conditions associated with mining the Galt Seam at Picture Butte. The 1983 Geotechnical Program at Picture Butte is described in detail (Section 5).

## 1.2 REFERENCES

The following references are used throughout this report:

**F. Grant, et al.**

1953 - 1971: Untitled; Seven papers on roofbolting, subsidence, ground stress in Lethbridge and Canadian mines.

**I.D. Crawford**

1947: The Geology and Structure of the Lethbridge Coalfield; MSc Thesis, University of Alberta.

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1978: Geotechnical Review of Applicability of Shortwall Mining in the Lethbridge Coalfield.

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**Norwest**

1979a: 1979 Data Package for the Lethbridge Coal Project.

1979b: Maps to Accompany 1979 Data Package for the Lethbridge Coal Project.

**Robinson, Dames & Moore**

1980a: Report on Subsidence Study, Lethbridge Coal Project, Lethbridge, Alberta.

1980b: Review of Groundwater Hydrology Conditions, Lethbridge Coal Project, Lethbridge, Alberta.

**Associated Mining Consultants Ltd.**

1980 Kipp Mine Project (AR-32, for Petro-Canada)
Vol. 1 Project Assessment - Factual Summary.
Vol. 2 Document Summaries

**Petro-Canada**

1980: Untitled: Field Operations and Structural Geology - Site Report.

**Norwest (G. Jordan)**

1980: 1980 Exploration Report on Lethbridge Property.

**Petrofina, Daryl Thomas**

1980: Washability Analysis of Core, 1975 & 1980.

**Petrofina, Eric Sundgaard**

1981: 1981 Exploration Report & Appendices - Report, Folio - Maps.

**Petrofina, Daryl Thomas**

1981: Laboratory Core Analysis and Washability Report.

**Golder Associates**

1981a: Geotechnical Evaluation of Bedrock, Proposed Decline and Test Mine, Lethbridge/Picture Butte Coal Property, Alberta; Report No. 8122028. To Petrofina Canada Inc.

1981b: Investigation of Soil Overburden for Proposed Decline Tunnel at the Shaughnessy/Picture Butte Coal Property; Report No. 8122028A. To Petrofina Canada Inc. Geotechnical

**Petro-Canada**

1982: Application to ERCB re TMP including Appendix I of letter to D. Henderson dated July 5, 1982 showing anticipated seam section and anticipated quality of ROM and copy of Drawing 6/2 showing support of Intersections.

**M.J. Hendry.**

1982: Hydraulic Conductivity of a Glacial Till in Alberta.

**Associated Mining Consultants Ltd./Golder Associates**

1983a: Trial Mining Program - Kipp (AR-61A)

1983b: A Technical Assessment of Picture Butte (AR-61B)

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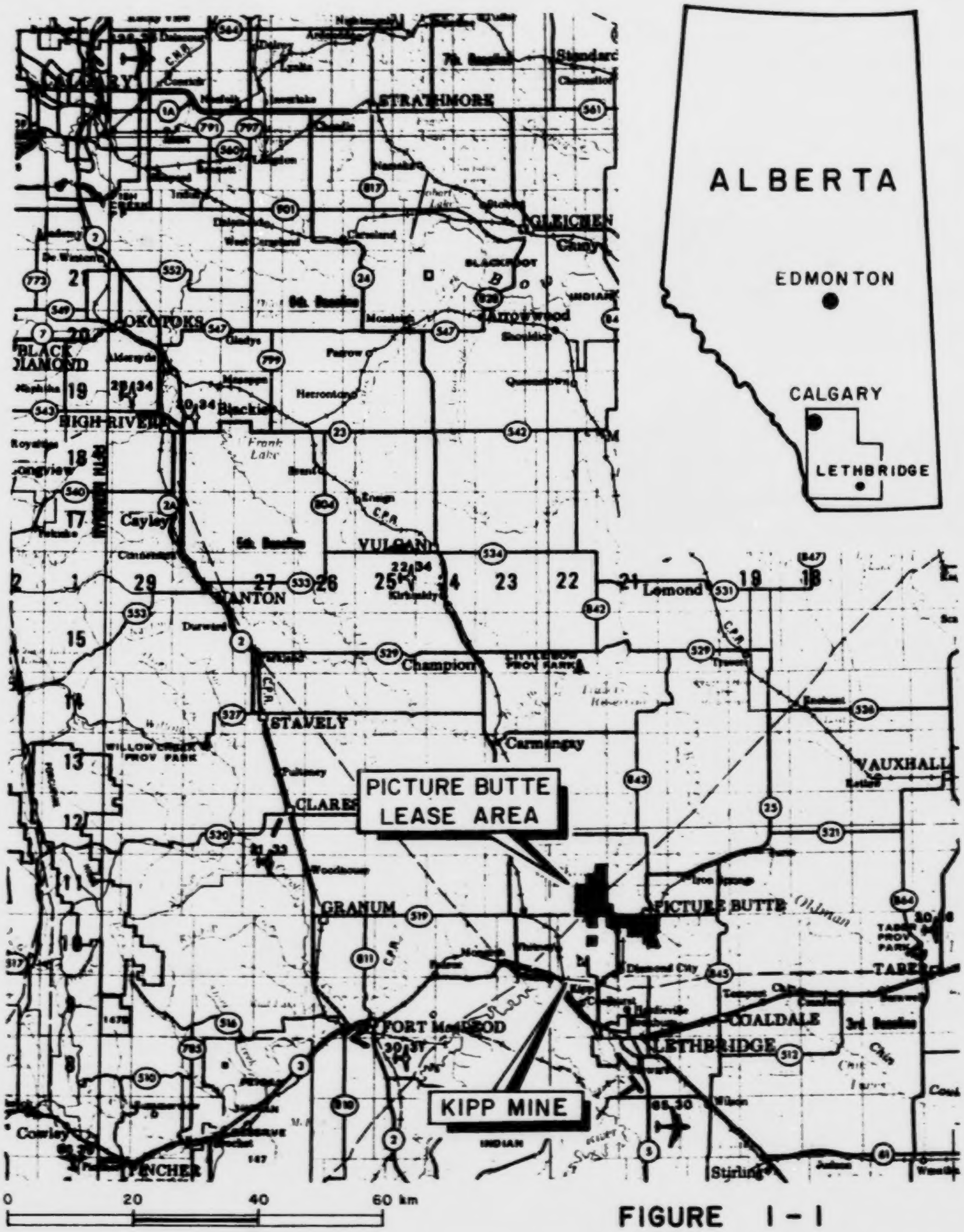
ALBERTA
EDMONTON
CALGARY
LETHBRIDGE
PICTURE BUTTE
LEASE AREA
KIPP MINE
STRATHMORE
GLEICHEN
OKOTOKS
BLACK DIAMOND
HIGH RIVER
Cayley
VULCAN
NANTON
Champion
STAVELY
Carmangay
CLARESHOLM
VAUXHALL
GRANUM
PICTURE BUTTE
FORT MacLEOD
COALDALE
LETHBRIDGE
PINCHER
Cowley
Stirling
0
20
40
60 km

FIGURE 1-1

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**1983**

LOCATION MAP

PA98, PA73-019

# PICTURE BUTTE COAL PROJECT
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1983

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2-1 Picture Butte Property

2-2 Generalized Stratigraphic Section - Lethbridge Area

# SECTION 2 - DESCRIPTION OF THE PICTURE BUTTE PROJECT AREA

## 2.1 LOCATION

The Picture Butte Property is situated to the south and west of the Picture Butte townsite, within the Lethbridge Coalfield; 20 km north of Lethbridge, Alberta. The extent of the PSRL lease is shown on Figure 2-1.

## 2.2 TOPOGRAPHY

The topography of the area consists of a gently undulating plain with a low, broad, northwest/southeast trending ridge to the northwest of the property which plunges towards the Picture Butte reservoir. Highway 519 cuts through the southern part of the property and several major irrigation canals flow through the area, supplying a network of smaller ditches which parallel section lines. Land use is primarily restricted to crop farming and, to a lesser degree, grazing.

## 2.3 GENERAL GEOLOGY

The Lethbridge Coalfield lies in the south-central Alberta Plains, on the east flank of the Alberta Syncline; the regional dip is to the west. The bedrock in the general study area is overlain by a variety of glacial, fluvio-glacial and glacio-lacustrine deposits. The area immediately to the northeast, northwest and southeast of Picture Butte is directly underlain by glacio-lacustrine silts and clays which overlie a silty and clayey till deposited during the Wisconsin advance of the Keewatin continental ice sheet. The till material is locally derived, and therefore, its composition largely reflects that of the underlying strata, generally consisting of clay and silt, with frequent sand and gravel layers. The glacial lake sediments are absent on the northwest-southeast trending ridge, and to the southwest of Picture Butte.

The bedrock in the area consists of massive mudstone of the Bearpaw Formation underlain by a sequence of laminated sandstone, siltstone, mudstone and coal of the Oldman Formation of the Belly River Upper Cretaceous Series. The upper part of the Oldman Formation contains numerous coal seams. The Galt Seam, which is the seam of economic interest, occurs near the top of the Oldman Formation. The general geologic sequence in the Lethbridge area is shown on Figure 2-2. The strata are generally flat lying, with a regional dip of at least I degree to the northwest.

A number of faults have been inferred from previous studies in the Lethbridge area, generally having a northwest to southeast strike direction. One major fault between Shaughnessy and the Kipp area has been interpreted to have a throw of approximately 30 m down on the south side. However, no major faults are thought to occur on the Picture Butte coal property. Mine plans from earlier operations indicate an almost random orientation for frequent faults with varying displacements, at the Standard Mine up to 3 m and at Galt #8 Mine up to 5 m.

## 2.4 GROUND WATER

The interpretation of the hydrology over the proposed mine area has limitations because of the sparse data. The conclusions drawn from previous studies in the Kipp and Picture Butte areas have been conflicting. Also, the anticipated hydrogeologic conditions of high flow through the Galt Seam predicted from previous surface exploration at Kipp prior to the sinking of the shaft were not encountered in the shaft sinking operations nor in the underground mining operations. Consequently, certain assumptions have been made relative to the effects of geology on the hydrogeologic regime over the area. Groundwater data obtained during the 1983 exploration drilling program was used to confirm the assumptions made previously with respect to the effects of geology on the general groundwater flow regime, and also to determine whether potential exists for high groundwater inflow during mining.

The detailed stratigraphy of the material overlying the bedrock in the Lethbridge area is unpredictable and difficult to correlate. Furthermore, buried channels that are known to exist beneath later deposits outside the immediate project area complicate the general hydrology of the Lethbridge area, although no such channels are thought to exist across the PSRL lease area.

## 2.5 SURFACE WATER

The Picture Butte area is traversed by an irrigation system consisting of ditches and canals. The hydraulic gradients of the flow system across the area are highly sensitive, with low water levels and nominal flows that supply large areas of farmland. Water levels and supply are controlled by a system of weirs and 'turn-out' water diversion structures that are constantly monitored to ensure adequate supply to farmland.

The major surface feature in the lease area is the Piyami Coulee, where stream flows are to the southeast and discharge into the Oldman River south of Picture Butte. Surface erosion has exposed the Galt Seam in the coulee and has resulted in a general reduction in bedrock cover over the seam.

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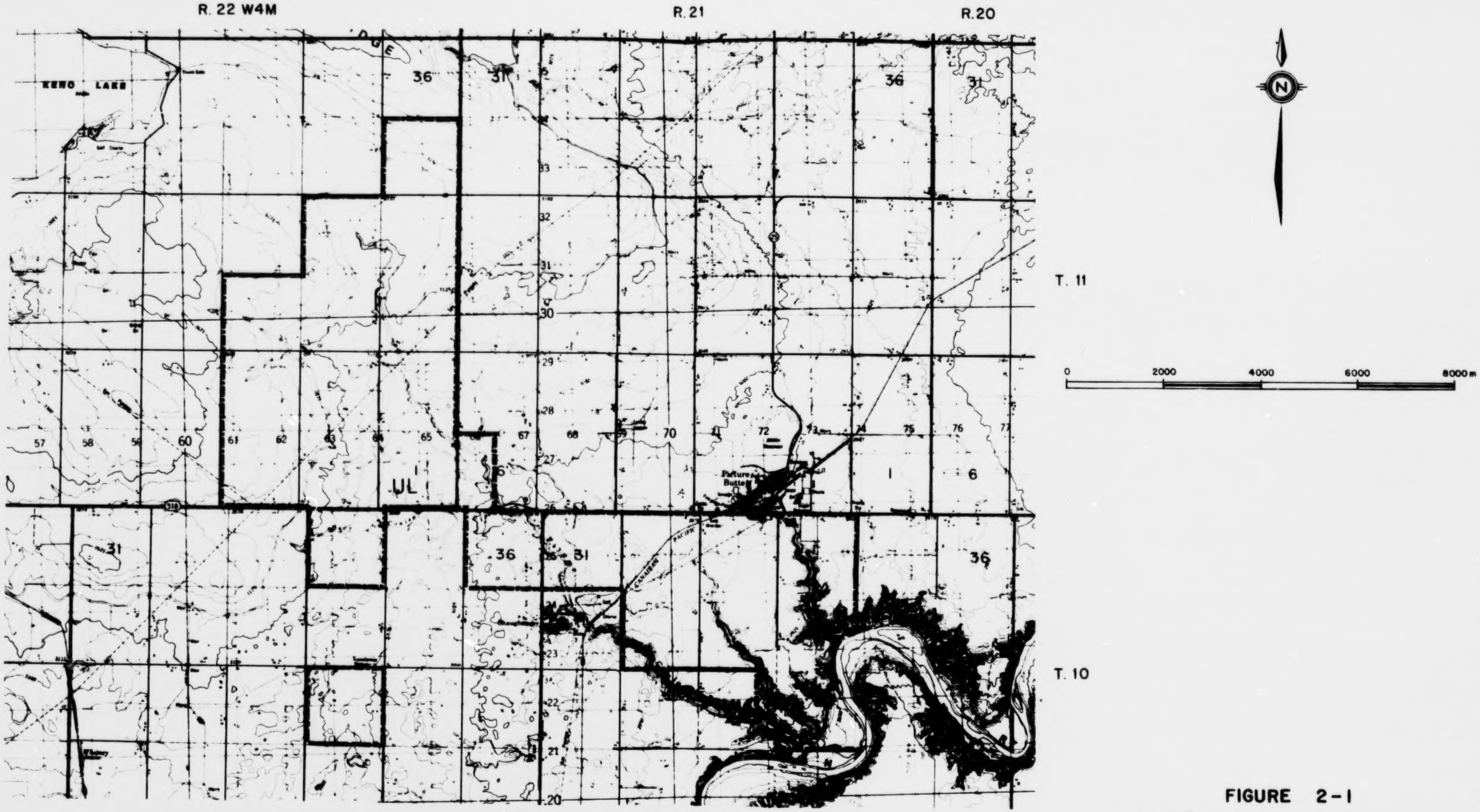
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R. 21
R. 20
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T. 11
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Picture Butte
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T. 10

FIGURE 2-1

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1983

PICTURE BUTTE PROPERTY

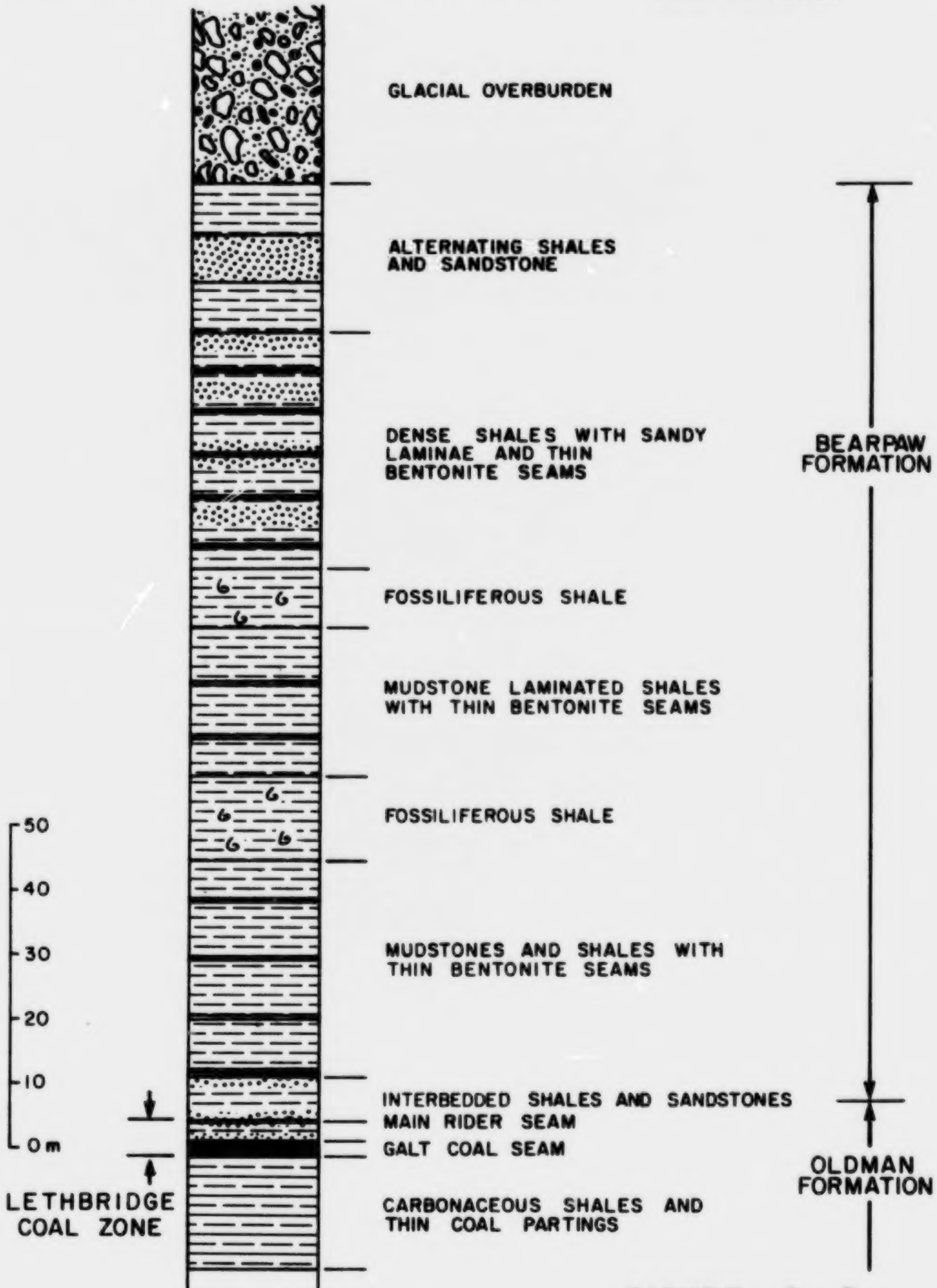
GLACIAL OVERBURDEN
ALTERNATING SHALES AND SANDSTONE
DENSE SHALES WITH SANDY LAMINAE AND THIN BENTONITE SEAMS
FOSSILIFEROUS SHALE
MUDSTONE LAMINATED SHALES WITH THIN BENTONITE SEAMS
FOSSILIFEROUS SHALE
MUDSTONES AND SHALES WITH THIN BENTONITE SEAMS
INTERBEDDED SHALES AND SANDSTONES
MAIN RIDER SEAM
GALT COAL SEAM
CARBONACEOUS SHALES AND THIN COAL PARTINGS
BEARPAW FORMATION
OLDMAN FORMATION
LETHBRIDGE COAL ZONE
50
40
30
20
10
0 m

FIGURE 2-2

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**1983**

GENERALIZED STRATIGRAPHIC SECTION
LETHBRIDGE AREA

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FIGURES
(Following Text)

3-1 Initial Roof Stability Plan
Trial Mining Program - Kipp

# SECTION 3 - RESULTS OF THE TRIAL MINING PROGRAM

## 3.1 INTRODUCTION

The Trial Mining Program (TMP) at Kipp Mine added significantly to the existing data base for mining the Galt Seam. The actual TMP carried out from July to October 1982, is described in Report AR-61A **'Picture Butte Coal Project - Trial Mining Program - Kipp'.**

This section goes beyond the direct observations from the TMP to discuss our interpretation of some potential causes and effects of the strata behaviour observed at Kipp. Strata behaviour and its control is obviously site specific; however, there are some underlying behavioral characteristics that may be applicable to the mining conditions at Picture Butte.

## 3.2 STRESS DISTRIBUTION

### 3.2.1 Mining Evidence

Roof conditions at the face of 1 South and 2 South roadways prior to the installation of the roof supports are shown on Figure 3-1. The immediate roof spalling, as the face was advanced, occurred in approximately one half of the total driveage of 1 South and 2 South and was confined principally to the east rib portion of the roadways. No immediate roof spalling was encountered in 3 West, 4 West and 5 West.

The TMP driveage started in 1 South, with a change in the mining horizon, at the old head end left by Petro-Canada in 1981 to 3 West. This portion of 1 South had immediate roof spalling conditions along the east rib. Initial roof support was roof bolts and steel straps, and steel girders. In the TMP steel straps were always used with roof bolts and subsequent mention of roof bolts should be taken to include steel straps.

3 West was then driven in a south-westerly direction parallel to the cleat with no immediate roof spalling. Initial support was roof bolts and steel girders.

When 2 South was driven south past the future 4 West junction no immediate roof spalling occurred as the roadway advanced. Initial support included roof bolts and steel girders.

1 South was then driven south from 3 West to 4 West. The initial roof support over most of this driveage was roof bolts and wood booms. This support system was not adequate to prevent immediate roof spalling. The change over to steel girders from Set #62 to Set #76, 15 m of driveage, was unable to arrest the immediate roof spalling. All wood booms were replaced by steel girders and later centre-posted to secure this section of 1 South.

4 West was then driven in a westerly direction with no immediate roof spalling. Initial roof support was roof bolts and wooden booms.

2 South was then driven south from 4 West with a change in the mining horizon. Initial roof support was roof bolts and wood booms. Immediate roof spalling occurred as shown on Figure 3-1. The wood booms had to be replaced by steel girders to secure this portion of 2 South roadway.

5 West was then driven east to 1 South with a change in the mining horizon. Initial roof support was roof bolts and wood

booms. There was no immediate roof spalling during this driveage.

I South was then driven north from 5 West to 4 West. Initial roof support was roof bolts and steel girders. The only immediate roof spalling occurred at the high stress breakthrough area at 4 West as shown on Figure 3-I.

5 West was then driven easterly from I South with another change in the mining horizon to completion of the TMP. Initial roof support was roof bolts and a combination of wood booms and steel girders. There was only a small amount of roof spalling up to the fault plane as shown in Figure 3-I.

### 3.2.2 Deduced Stress Field

The immediate behaviour of the roof tends to support the hypothesis of a stress field with the major axis plunging in a south-westerly direction, approximately parallel to the cleat and the minor axis approximately normal to the cleat. No quantitative figures can be assigned to this hypothetical stress field deduced from observations made in the TMP.

### 3.2.3 Discussion

Consider the directions of this deduced stress field (Figure 3-I) and its effect on the roof strata at the faces of the north-south, south-north driveages in the TMP.

#### a. I South/2 South - Advancing South

The high concentration of stress in the roof strata and coal face is just ahead of the east rib of the roadway; when the coal is removed this high stress in the roof strata causes failure of immediate roof strata, thereby initiating a roof failure mode along the east rib. The stress on the coal and roof strata just ahead of the west rib has been partially de-stressed a short distance into the coal face, therefore, when this coal is mined this roof remains stable. The roof failure mode initiated along the east rib, if artificial roof supports (roof bolts, booms, posts, etc.) are inadequate, will gradually lead to roof failure across the roadway.

### b. 1 South Advancing North

The high concentration of stress in the roof strata and coal face is now just ahead of the west rib, somewhat reduced by the direction of the stress field which transmits stress from the roof strata to the west coal pillar, the roof along the west rib remains stable on mining advance. The stress on the coal face and roof strata just ahead of the east rib has been partially de-stressed a short distance into the coal face, therefore, when this coal is mined this roof remains stable. This section was supported by roof bolts and steel girders. The roadway was also narrowed over a portion of this north direction driveage. This section was the most stable of the 1 South driveage and remained so until the steel girders were removed from the test section.

## 3.3 ROOF STRATA BEHAVIOUR

The behaviour of the roof strata was monitored during the TMP by roof extensometers, convergence rods, load cells and survey levels. The data indicates that bed separation in the north-south roadways took place above the bolting horizon, 1.8 m above the mining roof, particularly along the eastern part of 1 South and the central and eastern part of 2 South near the 4 West junction.

This bed separation was not observed in 3 West, 4 West and 5 West. As described in Section 3.2, the deduced stress field is thought to initiate the strain (bed separation) in the north-south heading. The very low tensile strength of the roof strata perpendicular to bedding allows bed separation to continue upwards into the immediate roof with time.

Caving characteristics demonstrated in I South test section show a very small particle size in the caved rock mass and a relatively high initial (5 m) cave above a narrow development roadway. This roof fall indicates that caving characteristics of this roof strata will pose no impediment to longwall mining.

## 3.4 CONCLUSIONS

The results from the TMP in Kipp Mine indicate the following:

a. Roadways driven east to west, west to east, and in a southwesterly direction parallel to the main cleat exhibited much better roof conditions than those driven in a north to south or south to north direction.

b. Roof conditions in 2 South were slightly better than those found in I South. The east rib of I South sheared parallel to the rib line and dropped in the order of 30 cm from its mining horizon; shear fractures were observed along the east rib up to 60 cm above the roof line. The deduced stress field is interpreted to enhance this failure mode.

c. Test stations in 3 West and 4 West indicate that for the short term (months), roof bolts (fully resin-grouted Rebar and Swellex) alone are capable of supporting the roof.

d. Test Section I South indicates that over a very short term (weeks) roof sag along the east rib was accelerated with the removal of the roof to floor supports, and that roof bolts alone, as a support system, were inadequate. Roof collapse occurred in Test Section I South.

e. Floor heave in the development section was not excessive and was less than 5 cm for roadways 4.5 m and 5 m wide with pillars of coal between 25 m and 35 m between roadways.

f. The mine was very dry in the TMP with the exception of some very limited water seapage in the vicinity of I South/5 West junction and the fault zone in 5 West.

g. Instrumentation installed during the TMP has shown that roof extensometers installed immediately after initial development will give a good indication of the longer term roof condition, after only a short period of time. This indicates that strata conditions could be controlled more easily with available warning. This roof behaviour, in our experience, is quite different from that in Mountain/Foothills mines, where little or no warning is provided to the operator. It would be of great benefit to develop this predictability further.

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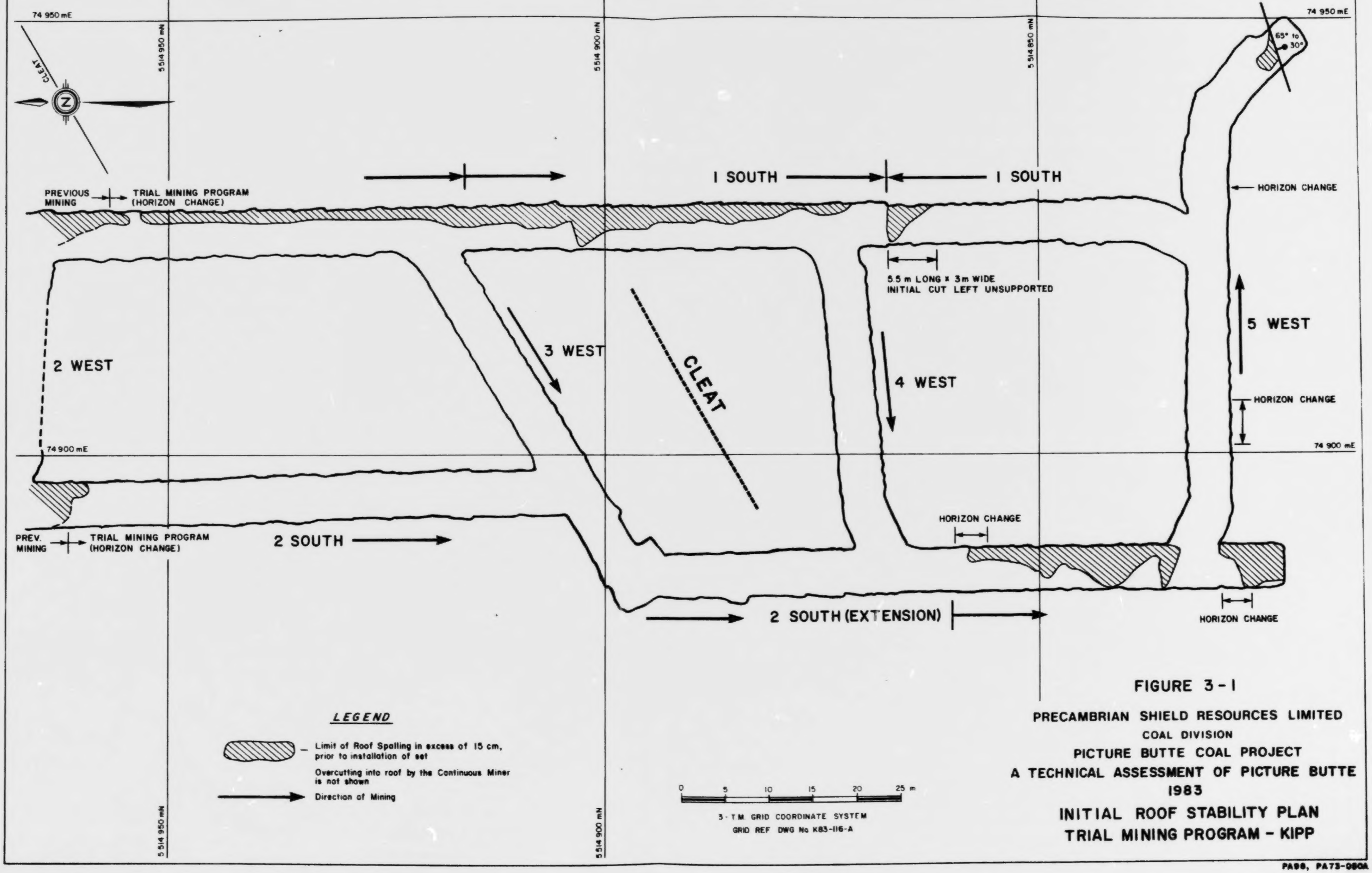
74 950 mE
5 514 950 mN
5 514 900 mN
5 514 850 mN
74 950 mE
CLEAT
N
65° to 30°
PREVIOUS MINING
TRIAL MINING PROGRAM (HORIZON CHANGE)
1 SOUTH
1 SOUTH
HORIZON CHANGE
5.5 m LONG x 3m WIDE INITIAL CUT LEFT UNSUPPORTED
5 WEST
2 WEST
3 WEST
CLEAT
4 WEST
HORIZON CHANGE
74 900 mE
74 900 mE
HORIZON CHANGE
PREV. MINING
TRIAL MINING PROGRAM (HORIZON CHANGE)
2 SOUTH
2 SOUTH (EXTENSION)
HORIZON CHANGE
LEGEND
▨ Limit of Roof Spalling in excess of 15 cm, prior to installation of set
Overcutting into roof by the Continuous Miner is not shown
Direction of Mining
0 5 10 15 20 25 m
3-TM GRID COORDINATE SYSTEM
GRID REF DWG No K83-116-A
5 514 950 mN
5 514 900 mN
PA98, PA73-080A

FIGURE 3-1

PRECAMBRIAN SHIELD RESOURCES LIMITED
COAL DIVISION
PICTURE BUTTE COAL PROJECT
A TECHNICAL ASSESSMENT OF PICTURE BUTTE
1983

INITIAL ROOF STABILITY PLAN
TRIAL MINING PROGRAM - KIPP

# PICTURE BUTTE COAL PROJECT
# A TECHNICAL ASSESSMENT OF PICTURE BUTTE
# 1983

## SECTION 4 - GEOLOGIC CORRELATION FROM KIPP TO PICTURE BUTTE

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# SECTION 4 - GEOLOGIC CORRELATION FROM KIPP TO PICTURE BUTTE

## 4.1 PURPOSE

The geologic correlation between Kipp and Picture Butte was carried out in order to extrapolate the strata characteristics and behaviour at Kipp during the TMP to Picture Butte. Particular emphasis was placed on cored drillholes in order that the geologic correlation could be used to correlate and extrapolate the geotechnical data from both areas, and apply the relevant data concerning mining acquired from the TMP at Kipp, to potential underground mining at Picture Butte.

The initial correlation was made from available geologic data which was abundant for the Kipp and Picture Butte areas, but very sparse for the intervening Shaughnessy block.

## 4.2 CORRELATION OF GEOLOGIC DATA

A detailed stratigraphic correlation was made between Picture Butte and the Kipp Mine. The lateral continuity of prominent lithologic units and their qualitative aspects were assessed to determine the similarities and differences in the depositional sequence between the two areas. This in turn allowed correlation of geologic units exhibiting similar mechanical behaviour and known physical properties.

### 4.2.1 Scope of Work

Drillhole information acquired during various exploration and geotechnical programs at Kipp, Picture Butte and Shaughnessy between 1975 and 1982 was studied, and preliminary geologic cross-sections constructed. Stratigraphic fence diagrams were also constructed for Kipp (Figure 4-1) and Picture Butte (Figure 4-2), and these were subsequently 'linked' by a third fence diagram across the Shaughnessy Area (Figure 4-3). Construction of the fence diagrams was made prior to the 1983 geotechnical drilling program, and used a limited number of drillholes concentrated in specific locations. The subsequent 1983 data does not significantly affect the conclusions drawn from these fence diagrams.

The Kipp and Picture Butte fence diagrams were constructed by plotting an isometric grid on which drillholes were located by means of their co-ordinates. The true location of some Picture Butte drillholes had to be shifted for reasons of clarity. In the Kipp fence diagram overcrowding of borehole profiles was avoided by increasing the north/south scale by 50% with respect to the east/west axis. For the Shaughnessy fence diagram true UTM co-ordinates were used to locate drillholes on an undistorted grid.

The lithological interpretation was presented for each drillhole in each of the fence diagrams together with its density log, with the exception of W-10 for which only an electrical resistance log was available. The geophysical logs had varying scales, and were photographically reduced (or enlarged) to a common scale.

### 4.2.2 Criteria

The most significant geologic parameters were identified, and used for the correlation, using the following criteria:

- continuity of the different coal horizons that comprise the Galt Seam.
- relative position of the Main Rider Seam.

- persistence of and facies changes within the Ostrea Shell Zone.
- location of bentonitic horizons, particularly in the immediate floor horizons.
- persistance of ferruginous siltstone bands.

Lithologs and their variations were established on the basis of their gamma, formation density, and where available, focussed resistivity responses. The thicknesses of the various strata were mainly determined from the focussed beam logs. In many cases, these also enabled a distinction to be made between carbonaceous mudstones and mudstone/coal laminae, as in drillholes 75-19, 75-20, W-7 and W-12. In some cases study of the gamma ray logs revealed the presence of bentonitic strata (indicated by a shift of some 10 to 20 API in the gamma ray flux).

In general terms, the different lithologies, and their response on the logs, were taken as follows:

| | **DENSITY** | **RESISTIVITY** (ohm.m) |
|---|---|---|
| Coal | Less than 1.7 | Greater than 100 |
| Argillaceous Coal | 1.70 - 1.85 | 60 - 100 |
| Carbonaceous Mudstone | 1.85 - 2.00 | 40 - 60 |
| Carbon Bearing Mudstone | 2.00 - 2.35 | 35 - 40 |
| Mudstone | 2.35 - 2.50 | Less than 35 |
| Siltstone | Greater than 2.5 | 30 - 35 |

These criteria were developed with reference to core descriptions where available, or from those of nearby drillholes. In the interpretation these values were used only as a general guide and were not strictly adhered to.

The correlation was made in the three areas taking the base of the Galt Seam, as recognized in Kipp, as the isochronous surface. It should be pointed out that the total 'Galt Seam Section' at Picture Butte as documented in previous reports includes coal splits below this reference horizon (Golder Associates; 1981, Norwest, 1979 and 1980; Petrofina, 1981).

### 4.2.3 The Kipp Area

The fence diagram for the Kipp area is shown on Figure 4-1, and the typical seam section on Figure 4-4.

#### a. Roof Strata

The roof sequence of the Galt Seam was correlated up to the Oldman-Bearpaw transition zone. The stratigraphic sequence in descending order to the Galt Seam comprises:

- Mudstone (Oldman and earpaw Formations) - Main Roof Strata

- Upper Rider Seam
- Mudstone } Main Rider Seam
- Lower Rider Seam
- Mudstone
- Siltstone
- Carbonaceous mudstone to coal } Immediate Roof Strata
- Silty Mudstone Band (Ostrea Shell Zone equivalent)
- Mudstone
- Galt-Rider (Argillaceous Coal)
- Mudstone

- Galt Seam

The total thickness of this sequence to the top of the Main Rider Coal Seam (Upper Rider Seam) remains fairly constant, with a general thinning of the sequence from 7.6 m (78-5) in the southwest, to 6.7 m (75-22) in the northeast. In the immediate Kipp mine area this sequence is approximately 7.0 m thick. The relative position of the different units within the sequence is also fairly constant, the only variables are some facies changes.

The thickness of the mudstone band immediately above the Galt Seam generally decreases in a northerly direction across the area from a maximum of approximately 0.7 m in the southwest to approximately 0.3 m in the northwest.

The Galt-Rider Seam, which occurs immediately above the roof mudstone band, consists of coal to argillaceous coal and is a constant feature across the Kipp area. This thin coal seam usually has a thickness of approximately 0.35 m, although in the mine itself it appears to decrease in thickness to 0.18 m.

The Ostrea Shell Zone does not appear at Kipp, but its horizon is represented on gamma and density logs, and is interpreted as being represented by a compact, cemented, silty mudstone with arenaceous laminae.

A carbonaceous mudstone to argillaceous coal band is located approximately 1.8 m to 2.0 m above the top of the Galt Seam and correlates well across the area. Overlying this unit is a 0.25 m thick, hard, competent, dark grey siltstone band, with occasional fine sandy laminae. The density log of 79-8 indicates that two such siltstone bands exist.

At the top of the sequence is the Main Rider Seam which comprises two coal seams, namely the Upper and Lower Rider, separated by a mudstone band. In the mine area the Lower Rider consists of argillaceous coal some 0.3 m thick. The Upper Rider Seam is between 0.4 m and 0.5 m thick. In the southwest and central area the Upper Rider Seam dominates whereas toward the northeast, the Lower Rider Seam tends to dominate. In 75-22 the Upper Rider occurs as a carbonaceous mudstone. Similarly, the Lower Rider in 75-3 also appears to occur as a carbonaceous mudstone. In 78-5 the Lower Rider appears to be absent from the roof sequence.

The Oldman-Bearpaw transition zone throughout the area appears gradational and is generally composed of mudstones. The Bearpaw Shales occur as dark grey, massive mudstones and shales with occasional bentonitic partings. The uppermost Oldman Formation Strata has a more varied lithology.

### b. The Galt Seam

The overall thickness of the Galt Seam at Kipp as encountered in drillholes varies from between 1.49 m (75-22) and 1.89 m (75-2) with an average thickness of 1.65 m (the thickness encountered in the Kipp Mine). According to the Norwest 1979 study, the thickness of the Galt Seam varies from 1.28 m to 1.89 m across the Kipp lease area. Over relatively short distances there are small variations in thickness which range between 6 cm and 9 cm, as exemplified by comparison of closely spaced drillholes (79-8, 79-9, 79-10 and 79-11).

The Galt Seam at Kipp consists of three coal bands split by two partings. The basic geophysical signature of the seam is consistant across the area, with the two partings occurring at predictable locations within the seam section. The main variation within the seam section occurs as an occasional thinning of the lower parting, from a maximum thickness of approximately 0.3 m to almost zero, as indicated in 75-2 and 78-7.

### c. Floor Strata

Between 0.05 m and 0.20 m below the base of the Galt Seam the lithology grades from carbonaceous mudstone to mudstone. A slightly strong, 0.3 m thick silty mudstone/siltstone band is located approximately 1 m below the seam, except in the southwest part of the property. Coal seams ranging in composition from argillaceous coal to carbonaceous mudstone are located within the immediate 2.0 m of floor strata and bentonitic bands within 2.0 m of the base of the Galt Seam. Lower down in the floor sequence the lithology grades into wavy bedded arenaceous siltstones and sandstones.

Drillholes 79-8, 82-1 and 82-3 intersected the coarser sequence approximately 2.4 m higher than anticipated which may be due to pre-Galt faulting and erosion (Norwest 1981).

## 4.2.4 The Shaughnessy Area

Only three geophysical logs (W-10, W-7 and W-12) were available along a northeast/southwest line connecting the Picture Butte and Kipp areas. However, a number of general trends were identified (Figures 4-3 and 4-4).

### a. Roof Strata

The dominance of the Lower Rider Seam in a northeasterly direction across Kipp continues in the Shaughnessy area. The Upper Rider Seam 'pinches' out and is absent north of W-12.

The Ostrea Shell Zone is absent in W-7, and occurs in W-12. The appearance of the shell bed between these drillholes coincides with the absence of the siltstone band which exists across the Kipp Area.

### b. Galt Seam

The Galt-Rider Seam which occurs in the Kipp Area merges with the Galt Seam between W-10 and W-7. The carbonaceous mudstone that occurs above the Galt-Rider in the Kipp Area undergoes a facies change to coal, and also appears to merge with the Galt Seam.

The Galt Seam section here has a total thickness of between 1.8 m and 2.7 m and appears to contain only one major mudstone parting.

### c. Floor Strata

At Shaughnessy the floor strata consist of mudstones and thin coal seams which are separated and underlain by a similar mudstone to that at Kipp and at Picture Butte (Figure 4-4). In W-7 and W-12 bentonitic horizons were identified within these mudstone units, as was occasionally the case in the Kipp Area.

## 4.2.5 The Picture Butte Area

The fence diagram constructed for the central region of the Picture Butte lease area is shown in Figure 4-2, and a typical seam section in Figure 4-4.

### a. Roof Strata

Consistent with the interpretation in the Kipp Area, the Galt Seam roof strata was correlated to just above the Main Rider

Seam. At Picture Butte the stratigraphic thickness from the Galt Seam to the top of the Main Rider varies from 2.8 m to 5.3 m. The stratigraphic sequence in descending order comprises:

- Mudstone (Oldman and Bearpaw Formations)

- Main Rider Seam
- Mudstone
- Ferruginous Siltstone/ Concretionary Ironstone
- Mudstone
- Ostrea Shell Zone
- Mudstone

Immediate Roof Strata

- Galt Seam

At Kipp, the Main Rider Seam comprises two coal seams separated by a mudstone band. In the south-central part of the Picture Butte lease area there is only one rider seam, above the Galt Seam. To the north and west up to three thin coal bands occur above the Galt Seam. This trend was indicated from drillhole PB 81-31 to drillhole PB 81-14 and was positively identified in the 1983 drillholes.

In contrast to the roof sequence encountered at Kipp, no carbonaceous horizons were identified between the Galt Seam and the uppermost and only Rider Seam in the south-central part of Picture Butte. However, in the north and west of the Picture Butte lease area carbonaceous mudstone bands were identified in drillholes PB 83-1, PB 83-2, PB 83-4 and PB 83-6.

In most available core descriptions the 0.4 m thick siltstone band, which generally occurs between the Galt Seam and the Main Rider Seam, was described as ferruginous. The density logs infer that this unit probably grades locally into a concretionary ironstone band (PB 81-13, PB 81-31, PB 81-25). Within the local south-central area illustrated in Figure 4-2, the ferruginous siltstone/-ironstone band appears to pinch out west of PB 75-23 and PB 75-19. It was encountered in all other drillholes to the west including PB 83-2, PB 83-4 and PB 83-6. The ironstone/ferruginous siltstone band may well be correlative with the Ostrea Shell Zone.

### b. Galt Seam

The Galt Seam at Picture Butte comprises four coal bands, the uppermost band referred to as Split #1 in Norwest's 1980 Report, being equivalent to the Galt Seam as recognized at Kipp. This main seam is underlain by a series of thin coal seams referred to by Norwest as Splits #2, #3 and #4 which are separated by mudstone and carbonaceous mudstone bands (Figure 4-4).

The maximum thickness of the total Galt Seam section encountered at Picture Butte is 3.8 m. However, the Galt Seam as it appears at Kipp correlates with Split #1 (or Main Seam) as recognized at Picture Butte. The thickness of Split #1 across the central Picture Butte area varies from approximately 1.5 m to 1.8 m with a general decrease to the west of the lease area. In the north of the lease area a prominent mudstone parting is located near the top of the seam and varies in thickness from 0.2 m to 0.3 m (PB 81-14, PB 81-31, PB 81-13 and PB 83-1). The thickness of this parting diminishes toward the west (PB 81-14, PB 75-23, PB 80-10, PB 75-19 and PB 83-6) where it is replaced by argillaceous coal. The absence of this carbonaceous mudstone parting in the west of the lease area (PB 83-2, PB 83-3, PB 83-4 and PB 83-5) corresponds with the general decrease in thickness of the seam in this area (1.3 m in PB 83-2, PB 83-4, PB 83-5 and PB 83-6). A thinner parting near the base of the seam (PB 83-6) is more erratic in its presence and composition.

### c. Floor Strata

The Split #1 immediate floor strata consists of a mudstone band ranging from a few centimetres up to 2 m thick, but is generally 1 m to 2 m in the Picture Butte area (referred to by Norwest 1980 as Band #1). This is underlain by a thin coal seam (Norwest's Split #2) which is in turn underlain by an interlayered sequence of mudstone and thin coal seams (Norwests' S3 and S4). The floor strata encountered in the north and west of the Picture Butte lease area consists of a carbonaceous mudstone band approximately 0.2 m to 0.4 m thick, which is underlain by a medium hard, dark grey mudstone. In PB 83-3, a 0.05 m thick band of bentonitic mudstone occurs at the base of the coal seam, overlying fissile carbon bearing mudstone, which, in turn, overlies massive mudstone.

In the north and west of the lease area the lower coal splits were identified from the geophysical logs, and are shown on Figures 5-2 to 5-7. The occurrence of the lower splits is somewhat erratic and is indicative of changing depositional environments. The lower coal splits are generally separated by mudstones and carbonaceous mudstone. In the central area, the thin coal splits below the Galt Seam may be absent (PB 81-25).

The available geologic data indicates that the lower coal splits (Norwest's Split #2, #3 and #4) will not be included in the economically mineable seam section. The floor will, therefore, be established on either mudstone or carbonaceous mudstone. This indicates the possibility of changes in depositional environment and local facies changes at the base of the Galt Seam (Split #1) cannot be completely precluded.

Information available to date, shows that the floor strata within 5 m of the base of the Galt Seam at Picture Butte does not include bentonite horizons. Thin bentonite bands, less than 0.1 m were identified in PB 83-1 approximately 5 m and 8 m below the base of the coal seam.

### 4.2.6 Structure

A number of faults have been inferred from previous studies in the Lethbridge area. One major fault between Shaughnessy and Kipp has been interpreted to have a 30 m displacement. However, no major faults are thought to occur at Picture Butte. The existence of faulting at Picture Butte was identified in core from the 1983 drilling program (PB 83-5). It is not possible to determine the orientation or displacement of this fault. However, mine plans from the Standard Mine and the Galt #8 Mine indicate an almost random orientation with varying displacements of up to 5 m.

## 4.3 CONCLUSIONS

The lithologic correlation across the Kipp/Picture Butte area enables several conclusions to be made. The main points are as follows:

a. At Picture Butte the total Galt Seam section comprises four coal bands, the uppermost (Split #1) is equivalent to the Galt Seam as recognized at Kipp.

b. In the south and central part of the Picture Butte lease area the mudstone parting between the Galt Seam and the Galt Rider that exists at Kipp is significantly thinner and the Galt Seam as defined in this area includes the Galt Rider Seam. It follows that there is no coal in the immediate roof in the southern part of the Picture Butte property.

c. To the north and northwest of PB 75-23 the Galt Rider Seam occurs up to 1.0 m above the top of the Galt Seam (PB 83-5 and PB 83-6). In drillholes PB 83-1 and PB 83-2, additional thin coal bands were identified in the immediate roof strata between the Galt Seam and Main Galt Rider. These thin coal bands have not been identified in other drillholes at Picture Butte or at Kipp. It is reasonable, therefore, to conclude that over most of the Picture Butte property the immediate roof strata will be the same as at Kipp.

d. In the central Picture Butte area the immediate roof sequence between the Galt Seam and the Main Rider is considerably thinner than at Kipp. At Kipp the Main Rider consists of two seams, approximately 6 m to 8 m above the Galt Seam. In the central part of the Picture Butte lease area only one main rider seam exists and is approximately 3 m above the Galt Seam. In the north of the lease area this distance increases up to 5.5 m (PB 83-2).

e. It is not possible to confidently correlate the interseam partings at Kipp and Picture Butte either on a location or lithologic basis. The parting near the top of the Galt Seam at Kipp (as used to define the roof in parts of the Kipp TMP) comprises different material than the partings that exist at Picture Butte. In the western extremity of the lease area partings in the main seam are not present (PB 83-2, PB 83-3, PB 83-4 and PB 83-5). In PB 83-1 a 0.25 m thick carbonaceous mudstone parting exists, and this is reflected by an increase in the overall seam thickness (1.6 m) intersected in this drillhole.

The parting near the top of the Galt Seam in the central Picture Butte area is considerably thicker than the parting near the top of the Galt Seam at Kipp.

f. The Ostrea Shell Zone that is occasionally present immediately above the Galt Seam at Picture Butte does not exist at Kipp, although it does appear to be represented by a silty mudstone band.

g. From geologic descriptions, geophysical responses, and from visual observations, the mudstone immediately below the Galt Seam (Split #1) in the southern and central part of the Picture Butte lease area appears to be similar to that encountered at Kipp. However, toward the northwest, the coal seam is immediately underlain by carbonaceous mudstone. The results from the laboratory testing program, see Section 5, indicate no significant difference in engineering properties of these lithologic units.

The above geologic parameters have been used in the evaluation of accumulated geotechnical data to predict the anticipated mining conditions at Picture Butte, see Section 7.

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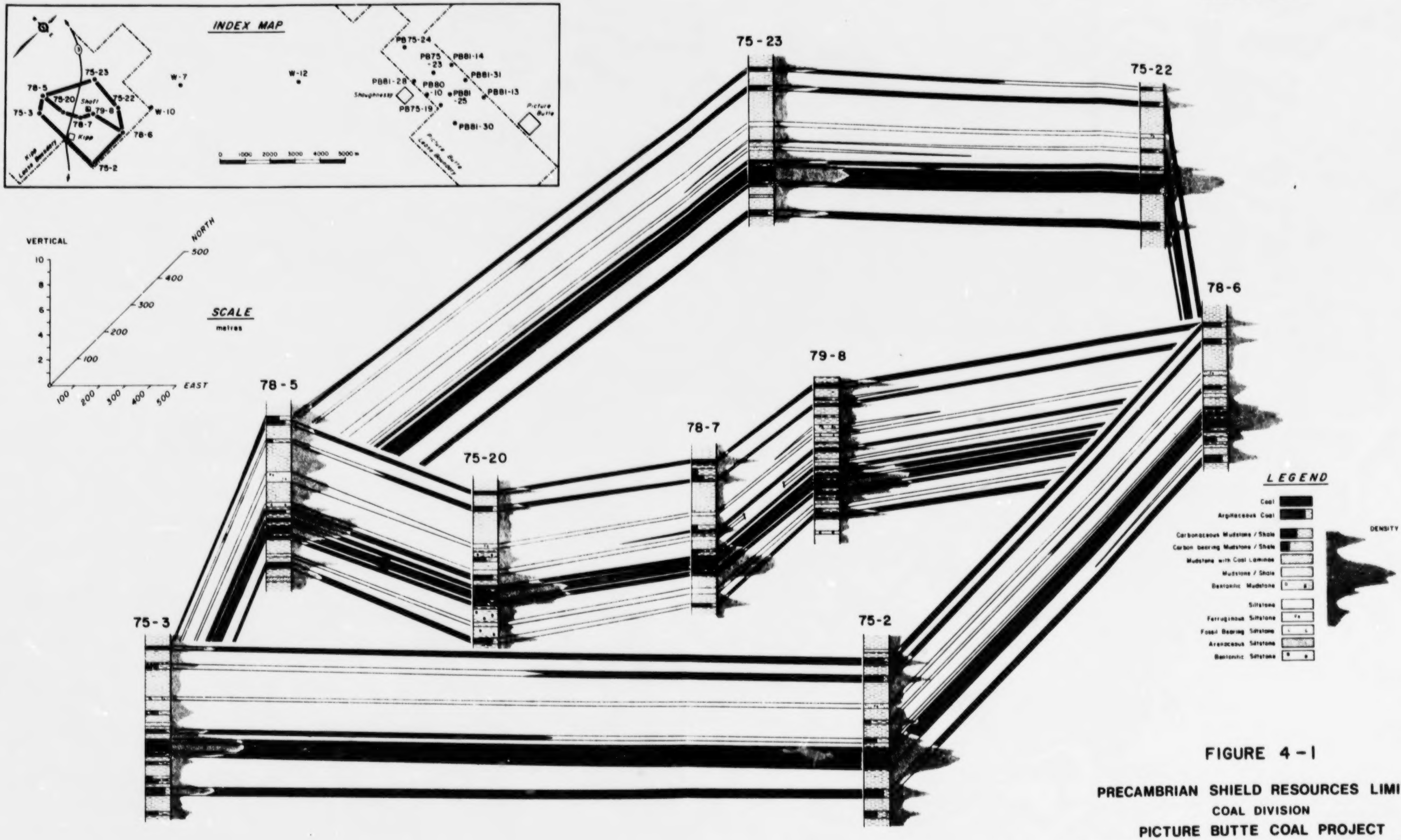
INDEX MAP
75-23
78-5
75-20
Shaft
75-22
W-7
W-12
75-3
79-8
W-10
78-7
Kipp
78-6
Kipp Lease Boundary
75-2
0 1000 2000 3000 4000 5000 m
PB75-24
PB75-23
PB81-14
PB81-31
PB81-28
PB80-10
PB81-25
PB81-13
Shaughnessy
PB75-19
Picture Butte
PB81-30
Picture Butte Lease Boundary
VERTICAL
10
8
6
4
2
NORTH
500
400
300
200
100
SCALE
metres
100 200 300 400 500 EAST
75-23
75-22
78-6
79-8
78-5
78-7
75-20
75-3
75-2
LEGEND
Coal
Argillaceous Coal
Carbonaceous Mudstone / Shale
Carbon bearing Mudstone / Shale
Mudstone with Coal Laminae
Mudstone / Shale
Bentonitic Mudstone
Siltstone
Ferruginous Siltstone
Fossil Bearing Siltstone
Arenaceous Siltstone
Bentonitic Siltstone
DENSITY LOG

FIGURE 4 - 1

PRECAMBRIAN SHIELD RESOURCES LIMITED
COAL DIVISION
PICTURE BUTTE COAL PROJECT
A TECHNICAL ASSESSMENT OF PICTURE BUTTE
1983
FENCE DIAGRAM
KIPP

PA98, PA73-003

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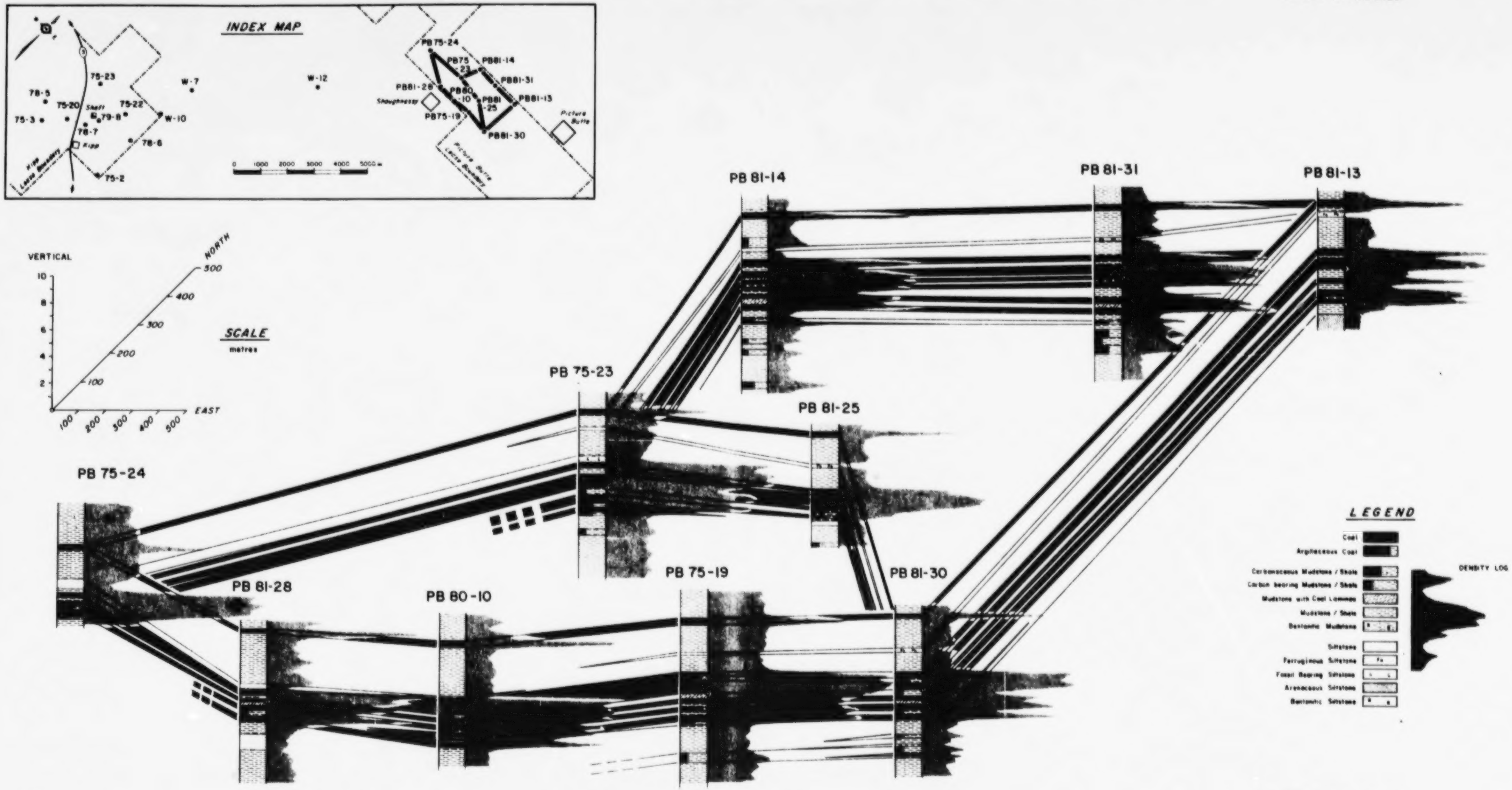
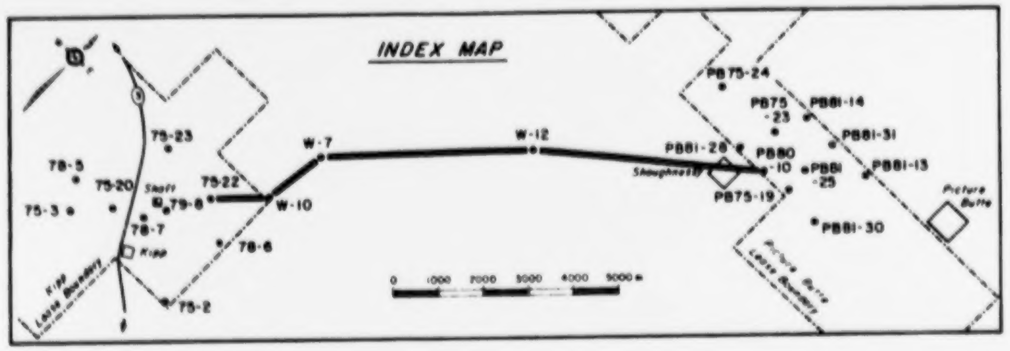
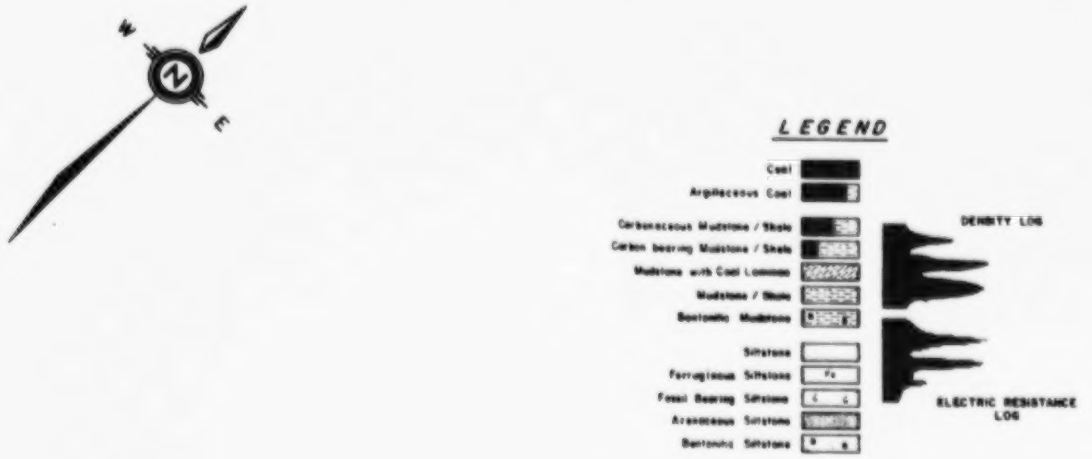

INDEX MAP
75-23
78-5
75-20
Shaft
75-22
75-3
79-8
W-10
78-7
Kipp
78-6
Kipp Lease Boundary
75-2
W-7
W-12
0 1000 2000 3000 4000 5000 m
PB75-24
PB75-23
PB81-14
PB81-31
PB81-28
PB80-10
PB81-13
Shaughnessy
PB81-25
PB75-19
PB81-30
Picture Butte
Picture Butte Lease Boundary
VERTICAL
10
8
6
4
2
NORTH
500
400
300
200
100
EAST
100
200
300
400
500
SCALE
metres
PB 81-14
PB 81-31
PB 81-13
PB 75-23
PB 81-25
PB 75-24
PB 81-28
PB 80-10
PB 75-19
PB 81-30
LEGEND
Coal
Argillaceous Coal
Carbonaceous Mudstone / Shale
Carbon bearing Mudstone / Shale
Mudstone with Coal Laminae
Mudstone / Shale
Bentonitic Mudstone
Siltstone
Ferruginous Siltstone
Fossil Bearing Siltstone
Arenaceous Siltstone
Bentonitic Siltstone
DENSITY LOG

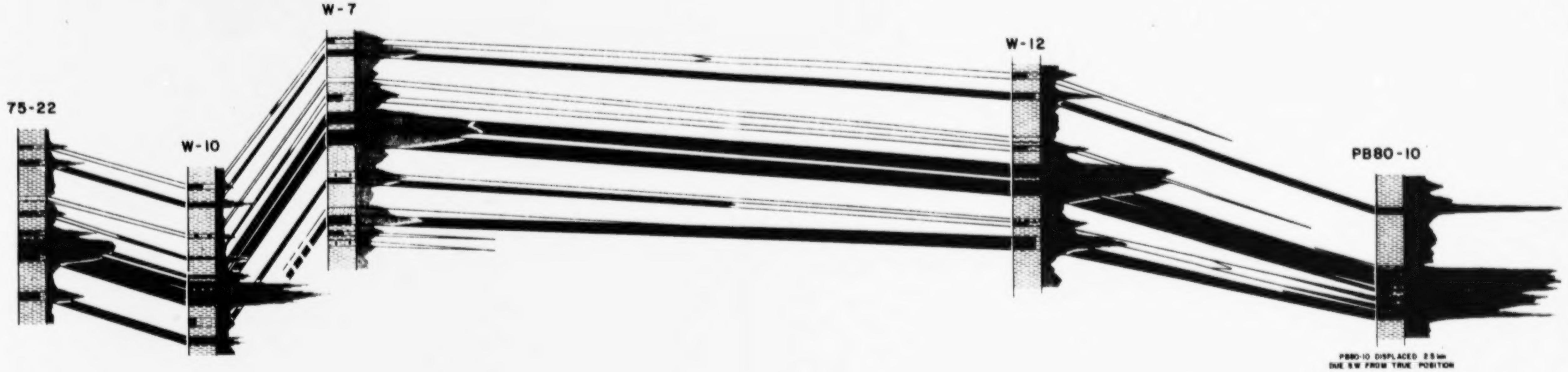
FIGURE 4-2

PRECAMBRIAN SHIELD RESOURCES LIMITED
COAL DIVISION
PICTURE BUTTE COAL PROJECT
A TECHNICAL ASSESSMENT OF PICTURE BUTTE
1983
FENCE DIAGRAM
PICTURE BUTTE

PA98, PA73-002


INDEX MAP
75-23
78-5
75-20
Shaft
79-8
75-22
75-3
78-7
Kipp
78-6
75-2
Kipp Lease Boundary
W-7
W-10
W-12
PB75-24
PB75-23
PB81-14
PB81-31
PB81-28
PB80-10
Shaughnessy
PB81-25
PB81-13
PB75-19
PB81-30
Picture Butte
Picture Butte Lease Boundary
0
1000
2000
3000
4000
5000 m


W
N
E
LEGEND
Coal
Argillaceous Coal
Carbonaceous Mudstone / Shale
Carbon bearing Mudstone / Shale
Mudstone with Coal Laminae
Mudstone / Shale
Bentonitic Mudstone
Siltstone
Ferruginous Siltstone
Fe
Fossil Bearing Siltstone
Arenaceous Siltstone
Bentonitic Siltstone
DENSITY LOG
ELECTRIC RESISTANCE LOG


75-22
W-10
W-7
W-12
PB80-10
PB80-10 DISPLACED 2.5 km DUE SW FROM TRUE POSITION

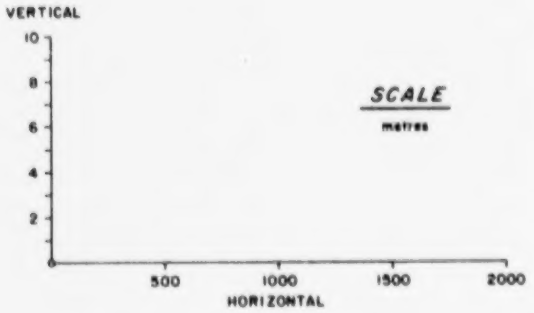

VERTICAL
10
8
6
4
2
500
1000
1500
2000
HORIZONTAL
SCALE
metres

FIGURE 4-3

PRECAMBRIAN SHIELD RESOURCES LIMITED
COAL DIVISION
PICTURE BUTTE COAL PROJECT
A TECHNICAL ASSESSMENT OF PICTURE BUTTE
1983

FENCE DIAGRAM
KIPP TO PICTURE BUTTE

PA98, PA73-001

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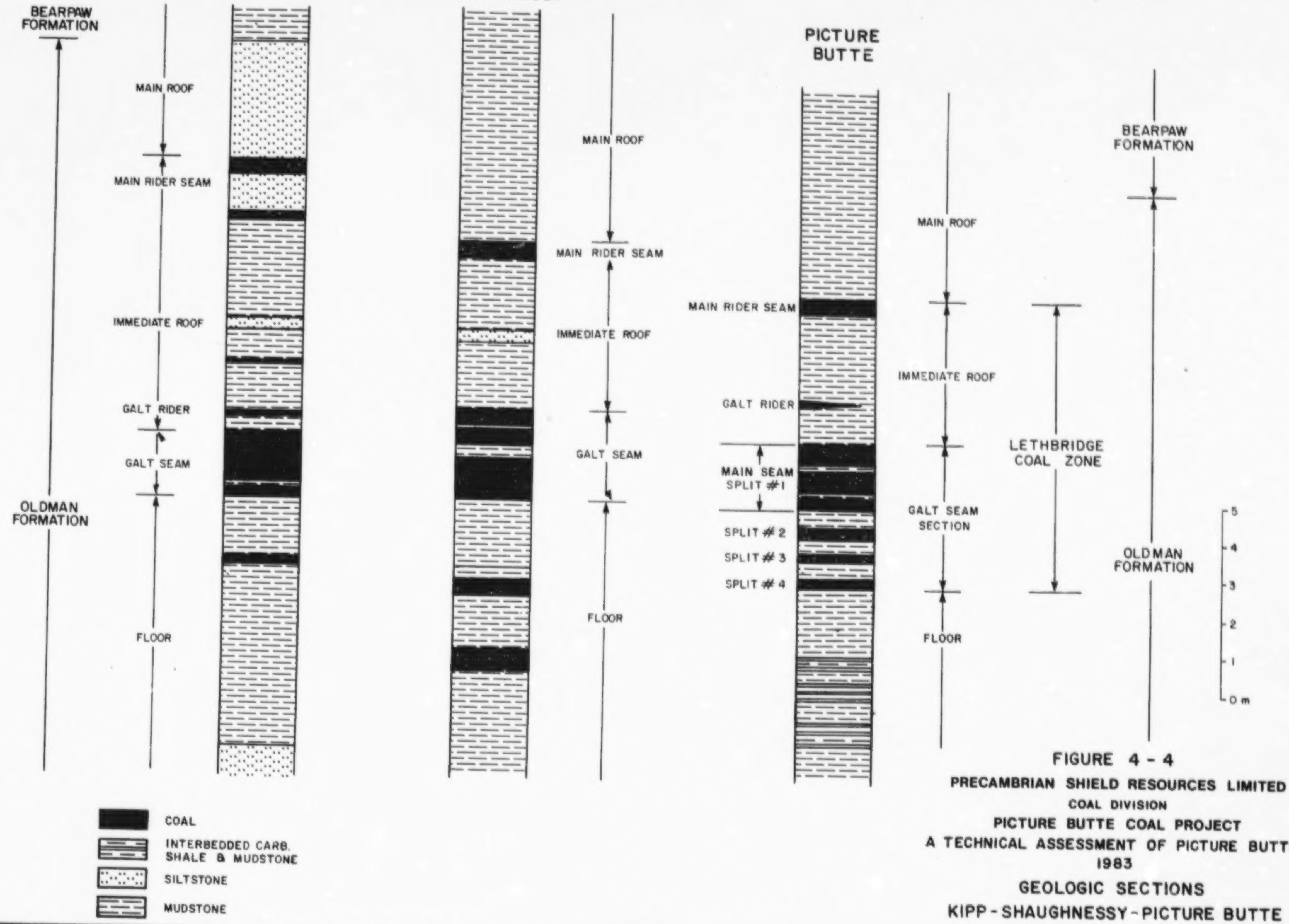
KIPP
SHAUGHNESSY
PICTURE BUTTE
BEARPAW FORMATION
OLDMAN FORMATION
MAIN ROOF
MAIN RIDER SEAM
IMMEDIATE ROOF
GALT RIDER
GALT SEAM
FLOOR
MAIN SEAM SPLIT #1
SPLIT #2
SPLIT #3
SPLIT #4
GALT SEAM SECTION
LETHBRIDGE COAL ZONE
5
4
3
2
1
0 m
COAL
INTERBEDDED CARB. SHALE & MUDSTONE
SILTSTONE
MUDSTONE

FIGURE 4 - 4

PRECAMBRIAN SHIELD RESOURCES LIMITED
COAL DIVISION
PICTURE BUTTE COAL PROJECT
A TECHNICAL ASSESSMENT OF PICTURE BUTTE
1983

GEOLOGIC SECTIONS
KIPP - SHAUGHNESSY - PICTURE BUTTE

PA98, PA79-035

# PICTURE BUTTE COAL PROJECT

# A TECHNICAL ASSESSMENT OF PICTURE BUTTE

## 1983

## SECTION 5 - THE 1983 PICTURE BUTTE GEOTECHNICAL PROGRAM

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# THE 1983 PICTURE BUTTE GEOTECHNICAL PROGRAM

## 5.1 GENERAL

The 1983 geotechnical data collection program was integrated with PSRL's exploration drilling program which was carried out between February 16 and March 2, 1982. Following the drilling program, detailed laboratory testing and data evaluation was carried out. In this section, the work is outlined and the results of the program are discussed. The data was subsequently assessed with respect to the previous geotechnical data from Kipp and Picture Butte, and this is discussed in detail in Section 6.

## 5.2 GEOTECHNICAL FIELD PROGRAM

The geotechnical program consisted of the following:

- core drilling
- detailed lithologic and structural core logging of seam sections
- installation of piezometers
- core photography
- selected sampling
- laboratory testing

### 5.2.1 Core Drilling

Six holes, numbered PB 83-1 through PB 83-6, were drilled at the locations shown in Figure 5-1. At each hole coring of both the floor and roof strata was carried out using a 3.05 m split tube core barrel (10' Christensen core barrel) and air flush and a 72.6 mm (3") I.D. tungsten carbide bit. All coring was carried out in the presence of a Golder Associates' geologist.

### 5.2.2 Core Logging

All core was logged immediately on removal from the core barrel in order to record its condition in an undisturbed state prior to handling and transportation. Geotechnical core logs are shown in Figures 5-2 through 5-7. Selected samples were wrapped in polyethylene to prevent moisture loss prior to laboratory testing.

The core was subsequently taken to Golder Associates Calgary laboratory for more detailed inspection and core photography.

### 5.2.3 Piezometer Installations

Sealed piezometer installations were made in drillholes PB 83-2, PB 83-4, PB 83-5 and PB 83-6. Attempts to place piezometers in PB 83-3 were unsuccessful because of problems with hole stability and water after removal of drill rods. The piezometer installations consisted of PVC Schedule 40 piezometer tubing, with 0.6 m slotted bottom sections. A clean pea gravel filter was placed around the slotted sections, and seals were created using bentonite.

Piezometers were installed in different geologic units. All installations were protected at the surface by metal casing. Schematic logs showing the different piezometer intervals are shown in Figure 5-8 along with piezometric levels monitored in the spring of 1983.

### 5.2.4 Core Photography

All drill core was photographed to provide a permanent visual record of ground conditions and the strata encountered above and below the Galt Seam. Core photographs are shown in Figures 5-9 through 5-14. Close-up photographs of structural and lithologic features are shown in Figures 5-15 and 5-16.

### 5.2.5 Selected Sampling

Representative core samples of the various lithological units encountered in the drillholes were selected for specific laboratory testing.

A complete list of sample locations and tests carried out is shown in Table 5-1.

### 5.2.6 Laboratory Testing

Laboratory testing was carried out in both Golder Associates Calgary and Vancouver laboratories. Specialized spectrographic analysis on 6 samples was performed by Geotex Consultants Ltd. of Vancouver, a certified chemical laboratory.

A total of 56 samples were subjected to a series of laboratory tests. Tests carried out were as follows:

- unconfined compressive strength
- slake durability
- free swell
- bulk density
- natural moisture content
- Atterberg limits
- X-Ray Diffraction

## 5.3 ROCK QUALITY

The following parameters were recorded in order to assess and systematically compare to the parameters determined by previous geotechnical programs:

- hardness
- bedding break intervals
- rock quality designation (RQD)

### 5.3.1 Hardness

Lithologic boundaries and zones of weakness were identified in drill core by systematically scratching the core with a knife as a rapid and simple means of identifying the relative hardness of the various lithologic units, arbitrarily classifying the most prominent mudstones as medium hard.

### 5.3.2 Bedding Break Intervals

Spacing measurements were carried out when the core was first exposed, and the bedding break spacings are shown on the geotechnical core logs (Figures 5-2 to 5-7). The logs should be used with reference to Table 5-2 which shows Deere's classification system for discontinuity spacing.

This parameter is highly subjective but general conclusions can be drawn:

- The bedding break spacing for the roof mudstones generally range from 0.1 m to 0.5 m (close to moderately close).
- The bedding break spacing for the floor mudstone generally ranges from 0.15 m to 0.6 m (close to moderately close).

- Bedding break spacing for the carbonaceous mudstones range between 0.05 m and 0.1 m (close).
- Bedding break spacing for the sandstone is generally moderately close to wide, ranging from 0.6 m to more than 1 m.

### 5.3.3 Rock Quality Designation (RQD)

Rock Quality Designation (RQD), is the cumulative axial length of intact rock which occurs in pieces longer than 0.1 m (unbroken by natural discontinuities) expressed as a percentage of the total core run, or of a nominal interval such as 1 m.

Rock quality designation measurements made over each run of core, or arbitrarily between certain lithologic boundaries, were recorded and are shown graphically on the logs. These should be used with reference to Table 5-3.

RQD values are generally 90% to 100% except for short coal intervals in the roof which were recorded as being zero. RQD values are almost solely derived from bedding breaks, with very little influence from jointing, shear zones or other tectonic disturbance.

### 5.3.4 Rock Structure

The joints observed in the core were generally inclined at 55° to 60° to the core axis, with planar, smooth surfaces, see Figure 5-15. Jointing is not intense.

The cleat in the coal has a significantly steeper dip, and is generally 10° to the core axis (Figure 5-16).

Possible faults were only observed below the Galt Seam. The most prominent fault structure observed in the core was recorded in PB 83-5 (190.0-190.8 m) as a zone of slickensided joints at approximately $40^{\circ}$ to the core axis, see Figure 5-6.

Shear zones were identified in the core and generally occur at the boundary between hard and softer strata units, see Figure 5-16.

## 5.4 LABORATORY TEST RESULTS

### 5.4.1 Uniaxial Compression Testing

Uniaxial compression testing was performed on 25 samples. The uniaxial compression test is the basic strength index test for rock strength classification. The test is easily performed in the laboratory on core samples. The results of these tests are presented in Table 5-4 which should be used with reference to Table 5-5. Examples of rock core before and after testing are shown in Figures 5-17 through 5-21.

Twelve tests were performed on various roof strata. The roof mudstones had a mean strength value of 14 MPa. The two tests carried out on carbonaceous mudstones in the roof recorded slightly lower values of 13 MPa. The test results from the ironstone bands in the roof vary considerably, but as expected, appear to be the strongest rocks in the sequence.

Three tests were carried out on Galt coal samples, indicating strengths of between 9 MPa and 20 MPa. Test results of 19 MPa and 21 MPa were recorded for coal samples taken from the coal splits in the Main Seam floor sequence.

Six floor mudstone samples were tested and recorded strength values of between 11 MPa and 31 MPa. One sandstone sample from the floor sequence recorded a value of 70 MPa.

### 5.4.2 Slake Durability

The slake durability test is designed to estimate the resistance of argillaceous rocks in particular to a combination of abrasion and moisture exposure. The slake durability index is obtained by rotating a standard sample of oven-dried material in a drum immersed in water. The drum is made of a standard mesh; material that breaks down under the tumbling action and passes through the mesh is discarded; material retained in the drum is oven-dried and weighed. The slake durability index is then calculated as the percentage ratio of final to initial dry sample weight. This procedure is repeated to obtain the slake durability index - second cycle, which is generally recommended.

Slake durability tests were performed on 20 samples to indicate the degree of disintegration that could result within the different strata horizons during mining operations, and to confirm the results from previous testing programs. The results of these tests are shown in Table 5-6 while typical examples are shown photographically in Figures 5-22 through 5-25.

Two slake durability tests on roof mudstones showed similar results, with values of 79% and 84% for the first cycle, and 20% and 22% for the second cycle.

Four tests were carried out on Galt coal samples with varying test results (second cycle varying between 24% and 90%).

Testing on floor mudstone samples gave values varying from 97% to 92% for the first cycle and from 92% to 76% for the second cycle. These values are significantly higher than previous test results from the south-central area and indicate a relatively high resistance to mechanical breakdown. Similarly, test results from the carbonaceous mudstones also indicate a high resistance to slaking with values of between 98% to 91% for the first cycle, and from 97% to 58% for the second cycle. As anticipated, the coal splits in the floor sequence exhibit slightly lower resistance to slaking, with second cycle values of between 75% to 45%.

### 5.4.3 Atterberg Limits

Atterberg limits were determined on 5 samples. The results are shown in Table 5-6. The lowest recorded plastic limit - the critical moisture content above which a clay reverts to the plastic state - was 28%. This is much higher than the in situ natural moisture content of approximately 10%, (Table 5-6), and indicates that, unless extremely wet conditions were to be artificially induced during mining operations, the floor strata would not become 'slick'.

Plasticity indices of 94 and 121 were recorded for bentonitic bands in the deep floor strata in Drillhole PB 83-1 (approximately 5.0 m below the base of the seam).

### 5.4.4 Free Swell

A total of 6 samples were allowed to swell freely in a consolidation machine under atmospheric pressure. The values indicating the relative volume change are shown in Table 5-7.

Generally, the swelling potential for floor mudstone is very low (1.2% to 1.7%), with the exception of Sample PB 83-6, 129.9 m to 130.2 m (1.8 m below the base of the coal seam), which recorded value of 3.4%.

As expected, the bentonite encountered approximately 5 m to 8 m below the Galt Seam in Drillhole PB 83-1 have a high potential for swelling (30%).

### 5.4.5 Bulk Density

Bulk densities determined for 5 samples are shown in Table 5-7.

### 5.4.6 X-Ray Diffraction Analyses

The presence or otherwise of expanding clay minerals could have significant implications for both roof and floor stability. Mineralogical identification of quartz and clay minerals was achieved qualitatively by x-ray diffraction These analyses were carried out by Geotex Consultants Limited, of Vancouver.

Seven samples of drill core were examined by means of x-ray diffraction. The location of samples tested, and their mineralogy are shown in Table 5-9. As expected, the mudstones in both the roof and floor contain major amounts of montmorillonite.

### 5.4.7 Rock Permeability Test

A laboratory permeability test was carried out on one sample from the roof strata in order to confirm the assumptions made from the study of hydrogeologic data, in the event that piezometric levels had not stabilized sufficiently to carry out field permeability tests prior to issuing this report.

A typical roof mudstone sample from PB 83-3 (239.3-239.48 m) was found to have a very low permeability of $4.3 \times 10^{-12}$ m/s.

## 5.5 GROUNDWATER

Piezometers installed in the 1983 drillholes and piezometric levels are shown in Figure 5-8.

Water was encountered in drillhole PB 83-3 at the bedrock/overburden boundary at a depth of 5 m, and water problems were experienced when drilling through broken sandstone strata thought to be part of the Edmonton Formation at a depth of 25 m (approximately 215 m above the Galt Seam) where production was estimated at approximately 8 L/s.

Water production did not significantly increase when drilling penetrated the coal seam, indicating that high water pressures do not exist in the coal seam.

Water level data recorded from piezometers installed at Picture Butte indicate that the water levels define a piezometric surface which decreases in elevation from northwest to southeast, which is probably the general direction of regional groundwater flow.

# TABLE 5-1

# PICTURE BUTTE COAL PROJECT

# A TECHNICAL ASSESSMENT OF PICTURE BUTTE

# 1983

## 1983 DRILLING PROGRAM

## LIST OF CORE SAMPLES SELECTED AND TESTED

| DRILLHOL Number | DEPTH (m) | GEOTECHNICAL UNIT | LITHOLOGICAL DESCRIPTION | TESTS CARRIED OUT |
|---|---|---|---|---|
| PB 83-1 | 158.9 - 159.1 | roof | ostrea shell bed | UC, PETR. |
| | 160.7 - 160.8 | roof | ironstone | UC |
| | 162.2 - 162.5 | roof | coal and carb. mudstone | UC, MC |
| | 163.0 - 163.1 | roof | carb. mudstone | UC |
| | 163.6 - 163.7 | Galt parting | carb. mudstone | UC |
| | 164.7 - 164.9 | floor | carb. mudstone | SD |
| | 164.9 - 165.0 | floor | mudstone | SD, PETR, X-R |
| | 165.0 - 165.2 | floor | mudstone | At, BD, FS |
| | 165.4 - 165.5 | floor | argillaceous coal | FS |
| | 165.6 - 165.8 | floor | coal (Split #2) | SD |
| | 165.9 - 166.0 | floor | mudstone | At, FS |
| | 166.0 - 166.2 | floor | mudstone | UC |
| | 166.6 - 166.8 | floor | coal (Split #3) | UC |
| | 167.4 - 167.5 | floor | carb. mudstone | MC |
| | 169.5 - 169.5 | floor | bentonite | At |
| | 169.8 - 170.0 | floor | bentonite | MC, At |
| | 172.7 - 172.8 | floor | bentonite | FS |
| PB 83-2 | 171.5 - 171.6 | roof | ironstone | UC |
| | 171.8 - 172.0 | roof | mudstone | MC |
| | 172.8 - 172.9 | roof | mudstone | UC, MC |
| | 173.2 - 173.4 | roof | coal | SD |
| | 173.5 - 173.7 | roof | mudstone | UC, SD |
| | 174.3 - 174.4 | roof | carb. mudstone | UC, MC |
| | 175.5 - 175.6 | Galt Seam | coal | SD |
| | 175.6 - 175.8 | floor | carb. mudstone | SD |
| | 176.1 - 176.2 | floor | silty mudstone | SD |
| | 177.9 - 178.0 | floor | carb. mudstone | UC |
| PB 83-3 | 239.0 - 239.1 | roof | ironstone | UC, PETR, X-R |
| | 239.3 - 239.5 | roof | mudstone | PERM |
| | 240.9 - 241.1 | roof | mudstone | UC, X-R |
| | 241.3 - 241.4 | Galt Seam | coal | UC |
| | 241.4 - 241.6 | Galt Seam | coal | UC, SD |
| | 243.7 - 243.9 | floor | coal (Split #2) | SD, BD |
| | 246.9 - 247.1 | floor | mudstone | UC |
| | 247.2 - 247.3 | floor | sandstone | BD |
| | 247.9 - 248.1 | floor | mudstone | MC, BD |
| PB 83-4 | 198.2 - 198.4 | roof | mudstone | UC |
| | 198.4 - 198.5 | roof | ironstone | BD |
| | 199.8 - 200.2 | roof | mudstone | SD, X-R |
| | 200.2 - 200.4 | Galt Seam | coal | SD |
| | 200.5 - 200.7 | Galt Seam | coal | UC |
| | 201.4 - 201.6 | Galt Seam | coal | SD |
| | 202.4 - 202.6 | floor | mudstone | UC, SD |
| | 205.4 - 205.6 | floor | coal (Split #3) | UC |
| PB 83-5 | 180.9 - 181.2 | roof | carb. b. mudstone | UC |
| | 182.6 - 182.8 | floor | carb. mudstone | SD |
| | 182.9 - 183.1 | floor | mudstone | UC, SD |
| | 183.6 - 183.9 | floor | mudstone | UC, SD |
| PB 83-6 | 125.8 - 135.9 | roof | mudstone | X-P |
| | 127.8 | Galt lower parting | carb. mudstone | At, X-R |
| | 128.2 - 128.3 | floor | carb. mudstone | SD |
| | 129.4 - 129.5 | floor | mudstone | UC, SD |
| | 129.5 - 129.6 | floor | mudstone | FS |
| | 129.9 - 130.2 | floor | mudstone | UC, SD, FS |

### LEGEND

| | | | |
|---|---|---|---|
| FS | Free Swell | PERM | Permeability Test |
| UC | Uniaxial Compression Test | PETR | Petrographic Analysis |
| BD | Bulk Density | X-R | X-Ray Diffraction Analysis |
| SD | Slake Durability | carb. | carbonaceous |
| MC | Moisture Content | carb.b. | carbon bearing |
| At | Atterberg Limits | | |

## TABLE 5-2
## PICTURE BUTTE COAL PROJECT
## A TECHNICAL ASSESSMENT OF PICTURE BUTTE
## 1983

### DEERE'S CLASSIFICATION FOR JOINT/FRACTURE AND BEDDING BREAK SPACING

| DESCRIPTION | SPACING OF JOINTS | ROCK MASS GRADING |
|---|---|---|
| Very Wide | $> 3$ m | Solid |
| Wide | 1 m to 3 m | Massive |
| Moderately Close | 0.3 m to 1 m | Blocky/Seamy |
| Close | 0.05 m to 0.3 m | Fractured |
| Very Close | $< 0.05$ m | Crushed and Shattered |

# TABLE 5-3

# PICTURE BUTTE COAL PROJECT

# A TECHNICAL ASSESSMENT OF PICTURE BUTTE

# 1983

## DEERE'S CLASSIFICATION FOR ROCK QUALITY DESIGNATION (RQD)

| RQD | ROCK QUALITY |
|---|---|
| 25% | Very Poor |
| 25 - 50% | Poor |
| 50 - 75% | Fair |
| 75 - 90% | Good |
| 90 - 100% | Very Good |

# TABLE 5-4

# PICTURE BUTTE COAL PROJECT

# A TECHNICAL ASSESSMENT OF PICTURE BUTTE

# 1983

## TEST RESULTS - 1983 DRILLING PROGRAM

## UNIAXIAL COMPRESSIVE STRENGTH

| LITHOLOGY | DRILLHOLE Number | DEPTH (m) | | MEAN DISTANCE Above (+) or Below (-) Galt Seam (m) | UNIAXIAL COMPRESSIVE STRENGTH (MPa) |
|---|---|---|---|---|---|
| | | from | to | | |
| Galt Coal | | | | | |
| | PB 83-3 | 241.3 | 241.4 | | 9.2 |
| | | 241.4 | 241.6 | | 20.0 |
| | PB 83-4 | 200.5 | 200.7 | | 13.2 |
| Mudstone (Roof) | | | | | |
| | PB 83-2 | 172.8 | 172.9 | +1.5 | 7.6 |
| | | 173.5 | 173.7 | +0.8 | 13.6 |
| | PB 83-3 | 240.9 | 241.1 | +0.3 | 28.7 |
| | PB 83-4 | 198.2 | 198.4 | +1.9 | 14.4 |
| | PB 83-5 | 180.9 | 181.2 | +0.2 | 14.5 |
| Carbonaceous Mudstone (Roof) | | | | | |
| | PB 83-1 | 163.0 | 163.1 | +0.1 | 12.5 |
| | PB 83-2 | 174.3 | 184.4 | +0.1 | 13.5 |
| Coal (Roof) | | | | | |
| | PB 83-1 | 162.2 | 162.5 | +0.8 | 14.5 |
| Ironstone (Roof) | | | | | |
| | PB 83-1 | 160.7 | 160.8 | +2.4 | 114.0 |
| | PB 83-2 | 171.5 | 171.6 | +2.9 | 83.2 |
| | PB 83-3 | 239.0 | 239.1 | +2.2 | 47.6 |
| Ostrea Shell Bed (Roof) | | | | | |
| | PB 83-1 | 158.9 | 159.1 | +4.1 | 16.5 |
| Mudstone (Floor) | | | | | |
| | PB 83-1 | 166.0 | 166.2 | -1.4 | 12.6 |
| | PB 83-4 | 202.4 | 202.6 | -1.1 | 16.0 |
| | PB 83-5 | 182.9 | 183.1 | -0.6 | 31.3 |
| | | 13.6 | 183.9 | -1.3 | 44.0 |
| | PB 83-6 | 129.4 | 129.5 | -1.2 | 11.3 |
| | | 129.9 | 130.2 | -1.8 | 12.7 |
| Carbonaceous Mudstone (Floor) | | | | | |
| | PB 83-2 | 177.9 | 178.0 | -2.3 | 4.8 |
| Coal (Floor) | | | | | |
| | PB 83-1 | 166.6 | 166.8 | -2.0 | 19.1 |
| | PB 83-4 | 205.4 | 205.6 | -4.1 | 20.7 |
| Sandstone (Floor) | | | | | |
| | PB 83-3 | 246.9 | 247.1 | -4.7 | 70.0 |

# TABLE 5-5

## PICTURE BUTTE COAL PROJECT

## A TECHNICAL ASSESSMENT OF PICTURE BUTTE

## 1983

### GOLDER ASSOCIATES STRENGTH CLASSIFICATION

| TERM | U.C.S. (MPa) |
|---|---|
| Very Strong | 100 - 200 |
| Strong | 50 - 100 |
| Moderately Strong | 12.50 - 50.00 |
| Moderately Weak | 5.00 - 12.50 |
| Weak | 1.25 - 5.00 |
| Very Weak | 0.60 - 1.25 |

# TABLE 5-6

# PICTURE BUTTE COAL PROJECT

# A TECHNICAL ASSESSMENT OF PICTURE BUTTE

# 1983

## TEST RESULTS - 1983 DRILLING PROGRAM

## SLAKE DURABILITY, MOISTURE CONTENT, AND ATTERBERG LIMITS

| Lithology | Drillhole | Depth (m) from | Depth (m) to | Mean Distance Above (+) or Below (-) Galt Seam (m) | Slake Durability (% Retained) 1st Cycle | Slake Durability (% Retained) 2nd Cycle | Moisture Content (%) | Atterberg Limits Liquid (%) | Atterberg Limits Plastic (%) | Atterberg Limits Plastic Index (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| **Galt Coal** | | | | | | | | | | |
| | PB 83-2 | 175.5 | 175.6 | | 47 | 24 | | | | |
| | PB 83-3 | 241.3 | 241.7 | | 96 | 90 | | | | |
| | PB 83-4 | 200.2 | 200.4 | | 95 | 83 | | | | |
| | PB 83-4 | 201.4 | 201.6 | | 77 | 31 | | | | |
| **Galt Carbonaceous Mudstone Parting** | | | | | | | | | | |
| | PB 83-6 | 127.8 | | | | | 112 | 34 | 78 | |
| **Mudstone (Roof)** | | | | | | | | | | |
| | PB 83-2 | 171.8 | 172.0 | +2.5 | | | 8.9 | | | |
| | | 172.8 | 172.9 | +1.6 | | | 8.4 | | | |
| | | 173.5 | 173.7 | +0.8 | 84 | 22 | | | | |
| | PB 83-4 | 199.8 | 200.2 | +0.2 | 79 | 20 | | | | |
| **Carbonaceous Mudstone (Roof)** | | | | | | | | | | |
| | PB 83-2 | 174.4 | 174.4 | +0.1 | | | 8.7 | | | |
| **Coal (Roof)** | | | | | | | | | | |
| | PB 83-1 | 162.2 | 162.5 | +0.8 | | | 9.3 | | | |
| | PB 83-2 | 173.2 | 173.4 | +1.1 | 88 | 70 | | | | |
| **Mudstone (Floor)** | | | | | | | | | | |
| | PB 83-1 | 164.9 | 165.0 | -0.2 | 96 | 81 | | | | |
| | | 165.0 | 165.2 | -0.4 | | | | 55 | 28 | 27 |
| | | 165.9 | 166.0 | -1.2 | | | | 71 | 32 | 39 |
| | PB 83-2 | 176.1 | 176.2 | -0.5 | 97 | 92 | | | | |
| | PB 83-3 | 247.9 | 248.1 | -5.7 | | | 8.3 | | | |
| | PB 83-4 | 202.4 | 202.6 | -1.1 | 96 | 82 | | | | |
| | PB 83-5 | 182.9 | 183.1 | -0.6 | 93 | 84 | | | | |
| | | 183.6 | 183.9 | -1.3 | 94 | 89 | | | | |
| | PB 83-6 | 129.4 | 129.5 | -1.2 | 93 | 79 | | | | |
| | | 129.9 | 130.2 | -1.8 | 92 | 76 | | | | |
| **Carbonaceous Mudstone (Floor)** | | | | | | | | | | |
| | PB 83-1 | 164.8 | 164.9 | -0.1 | 98 | 97 | | | | |
| | | 167.4 | 167.5 | -2.7 | | | 13.4 | | | |
| | PB 83-2 | 175.6 | 175.8 | -0.02 | 98 | 92 | | | | |
| | PB 83-5 | 182.6 | 182.8 | -0.3 | 94 | 67 | | | | |
| | PB 83-6 | 128.2 | 128.3 | -0.01 | 91 | 58 | | | | |
| **Coal (Floor)** | | | | | | | | | | |
| | PB 83-1 | 165.6 | 165.8 | -0.9 | 91 | 75 | | | | |
| | PB 83-3 | 243.7 | 243.9 | -0.5 | 75 | 45 | | | | |
| **Bentonite (Floor)** | | | | | | | | | | |
| | PB 83-1 | 169.5 | 169.6 | -4.8 | | | | 142 | 48 | 94 |
| | | 169.8 | 170.0 | -5.2 | | | 26.3 | 148 | 27 | 121 |

# TABLE 5-7

# PICTURE BUTTE COAL PROJECT

# A TECHNICAL ASSESSMENT OF PICTURE BUTTE

# 1983

## TEST RESULTS - 1983 DRILLING PROGRAM

## FREE SWELL

| LITHOLOGY | DRILLHOLE | DEPTH (m) from | DEPTH (m) to | MEAN DISTANCE ABOVE (+) OR BELOW (-) GALT SEAM (m) | FREE SWELL (%) |
|---|---|---|---|---|---|
| **Mudstone (Floor)** | | | | | |
| | PB 83-1 | 165.0 | 165.2 | -0.4 | 1.3 |
| | | 165.9 | 166.0 | -1.2 | |
| | PB 83-6 | 129.3 | 129.5 | -0.1 | 3.9 |
| | | 129.5 | 129.6 | -1.3 | 1.7 |
| | | 129.9 | 130.2 | -1.8 | 3.4 |
| **Argillaceous Coal (Floor)** | | | | | |
| | PB 83-1 | 165.4 | 165.5 | -0.7 | 0.3 |
| **Bentonite (Floor)** | | | | | |
| | PB 83-1 | 172.7 | 172.8 | -8.0 | 30.1 |

# TABLE 5-8

# PICTURE BUTTE COAL PROJECT

# A TECHNICAL ASSESSMENT OF PICTURE BUTTE

# 1983

## TEST RESULTS - 1983 DRILLING PROGRAM

## BULK DENSITY

| LITHOLOGY | DRILLHOLE | DEPTH (m) from | DEPTH (m) to | MEAN DISTANCE ABOVE (+) OR BELOW (-) GALT SEAM (m) | BULK DENSITY $g/cm^3$ |
|---|---|---|---|---|---|
| Ironstone (Roof) | | | | | |
| | PB 83-4 | 198.4 | 198.5 | +1.8 | 3.17 |
| Mudstone (Floor) | | | | | |
| | PB 83-1 | 165.0 | 165.2 | -0.4 | 2.38 |
| | PB 83-3 | 247.9 | 248.1 | -5.7 | 1.94 |
| Sandstone (Floor) | | | | | |
| | PB 83-3 | 247.2 | 247.3 | -4.9 | 2.46 |
| Coal (Floor) | | | | | |
| | PB 83-3 | 243.7 | 243.9 | -0.5 | 1.51 |

# TABLE 5-9

# PICTURE BUTTE COAL PROJECT

# A TECHNICAL ASSESSMENT OF PICTURE BUTTE

# 1983

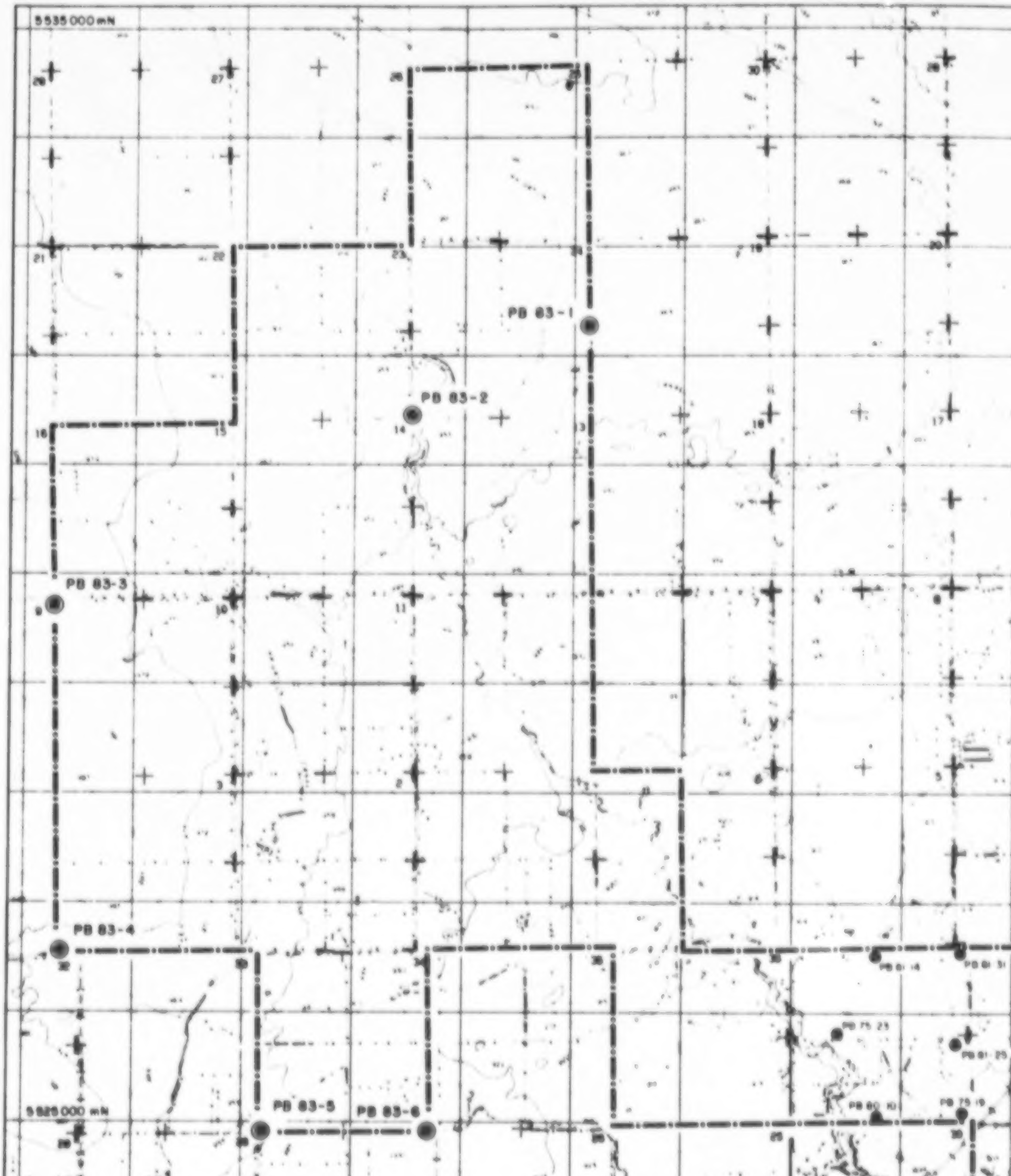
## TEST RESULTS - 1983 DRILLING PROGRAM

## X-RAY DIFFRACTION

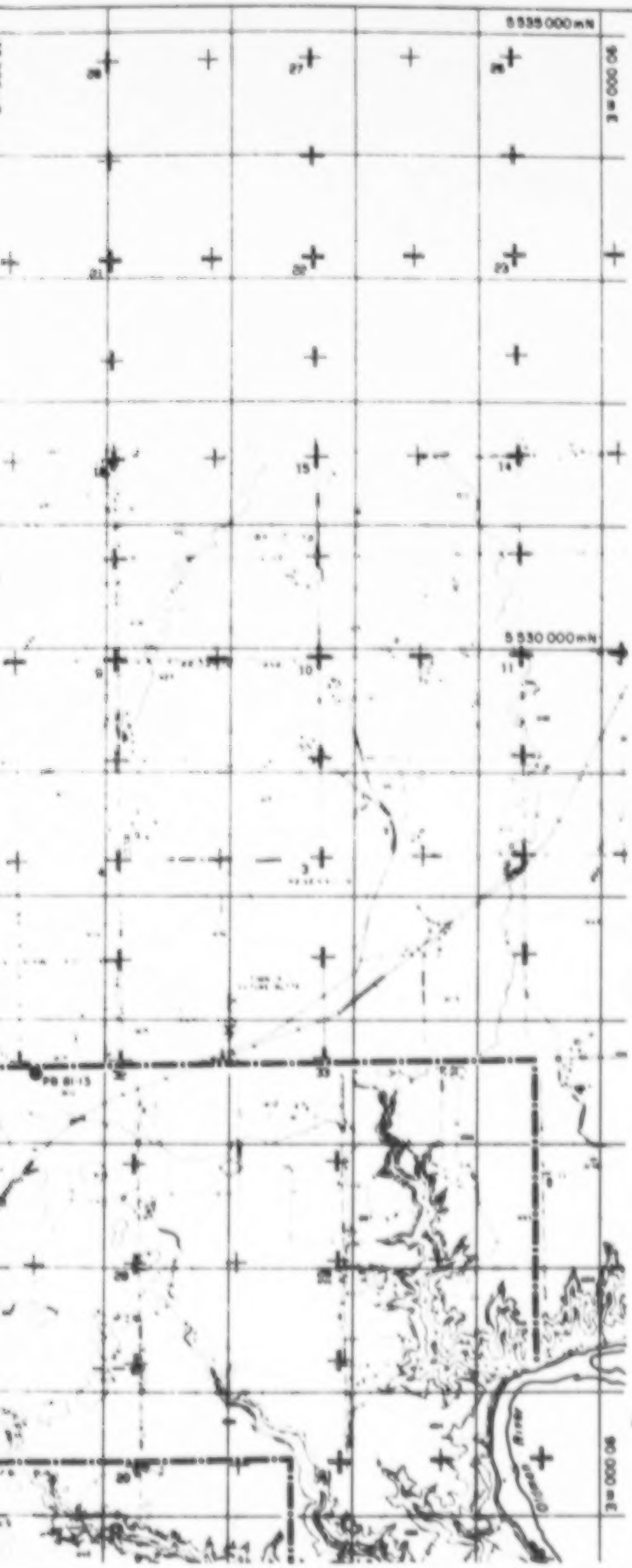
| Drillhole | Depth (m) From | Depth (m) To | Distance (m) Above (+) or Below (-) Galt Seam | Rock Type | Quartz | Plagio-clase | Carbon-aceous Fragments | Illite/ Muscovite | Kaolinite | Montmorril-lonite | Siderite | Calcite |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PB 83-1 | 158.9 | 159.1 | +4.1 | shell bed | -(3%)[1] | -(3%)[1] | 2%[1] | * | * | * | 72% | 20% |
| PB 83-1 | 164.9 | 165.0 | -0.2 | mudstone | -(5%)[1] | -(5%)[1] | 8%[1] | - | - | ++ | | |
| PB 83-3 | 239.0 | 239.1 | +2.2 | ironstone | -(1%)[1] | | 1%[1] | 0.1%[1] | | | 98% | |
| PB 83-3 | 240.9 | 241.1 | +0.3 | mudstone | - | tr | ø | - | - | ++ | | |
| PB 83-4 | 199.8 | 200.2 | +0.2 | mudstone | - | - | ø | - | + | ++ | | |
| PB 83-6 | 125.8 | 125.9 | +1.1 | mudstone | - | - | ø | | - | ++ | | |
| PB 83-6 | 127.8 | 127.83 | n/a | parting in seam | tr | | ø | | - | + | | |

LEGEND

| | |
|---|---|
| ø | present but not detectable by X-rays |
| tr | trace |
| ++ | dominant |
| + | major |
| - | minor |
| * | not x-rayed |
| 1 | Visually estimated mode based on framework only.<br>Percentage shown for quartz or plagioclase is the combind quartz and plagioclase content of the framework grains only.<br>Percentage shown is for framework muscovite only. |


5535000mN
PB 83-1
PB 83-2
PB 83-3
PB 83-4
PB 83-5
PB 83-6
5525000 mN
PB 81-14
PB 81-31
PB 75-23
PB 81-25
PB 80-10
PB 75-19
000 mE

**Associated Mining Consultants Ltd.**
**Golder Associates**


5535000mN
5530000mN
26
27
28
21
22
23
15
14
9
10
11
3
PB 81-13
32
33
26
20
River

N
0
1000
2000
3000
4000m
3-TM GRID COORDINATE SYSTEM
PSRL MAP BASE

***LEGEND***

- ● Drillhole used in Fence Diagram (prior to 1983)
- ◉ Drillhole 1983

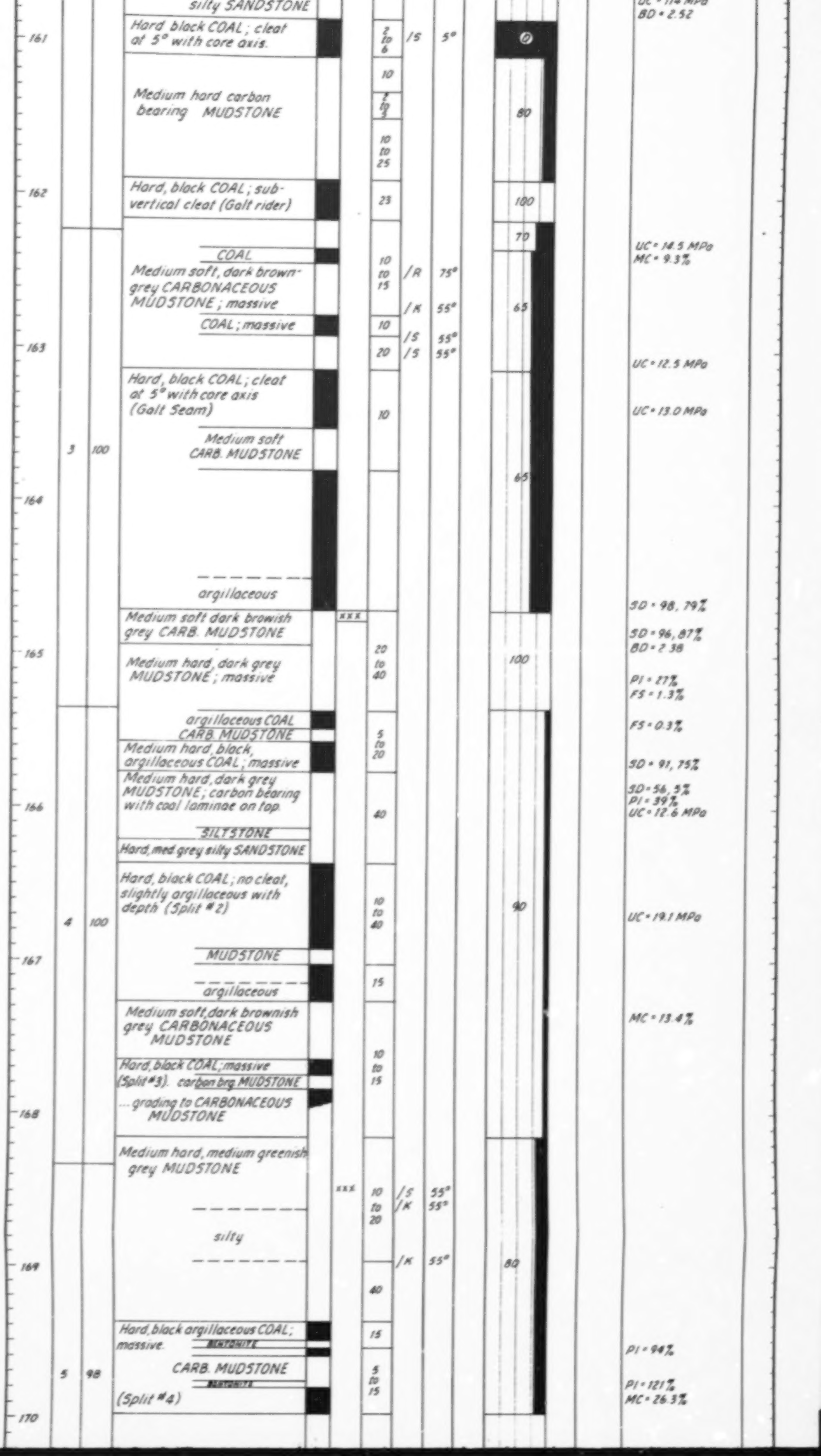
## FIGURE 5-1

PRECAMBRIAN SHIELD RESOURCES LIMITED
COAL DIVISION
PICTURE BUTTE COAL PROJECT
A TECHNICAL ASSESSMENT OF PICTURE BUTTE
1983

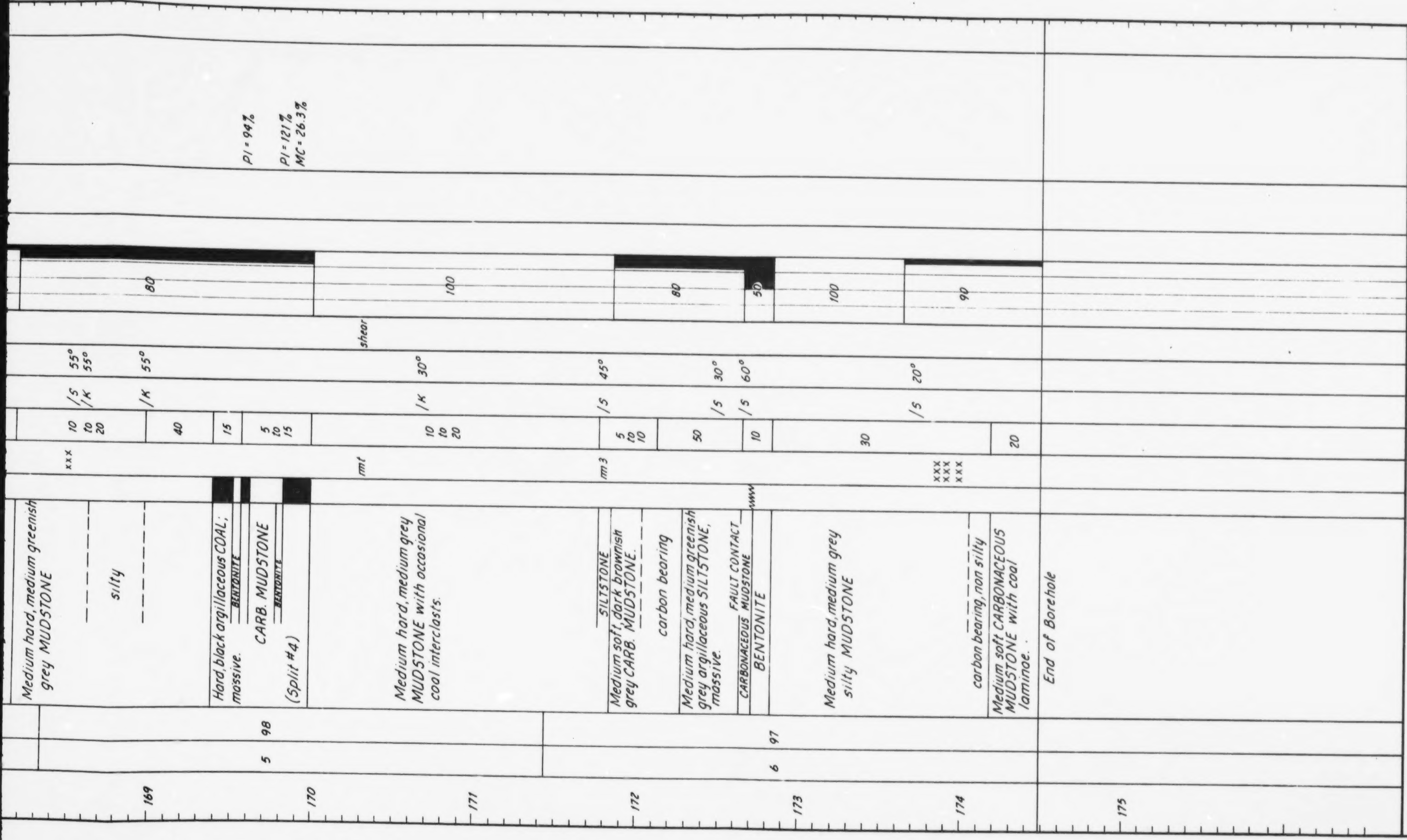
## DRILLHOLE LOCATION PLAN

PA98-060

| Depth m | Core Run No. | Recov. % | Lithologic Description | Log | Structure: Gouge (mm) Broken Zones | Structure: Bdg. Brk. Int. (cm) | Fractures: Roughness | Fractures: Dip | Fractures: Notes | Rock Quality Designation % | Test Results & Notes: Depth No. | Comp. Strength MPa | Slake Durability Elastic Modulus | Rock Class |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 156 | | | | | | | | | | 25 50 75 | | | | |
| | 1 | 100 | Medium hard, dark grey, massive MUDSTONE; trace of silt. | | m2 | 5 to 40 | /5<br>(5 | 70°<br>60° | | 100 | | | | |
| 157 | | | | | | | | | | | | | | |
| 158 | | | silty | | | 10 to 20 | | | | | | | | |
| 159 | | | Hard, med. grey, calcareous silty MUDSTONE; numerous Ostrea shells in pelitic matrix.<br>less shells | | | 20 to 25 | | | | | | | UC = 16.5 MPa<br>BD = 3.25 | |
| 160 | 2 | 100 | Med. hard, dark grey MUDSTONE with isolated shell fragments.<br>silty SANDSTONE | | | 20 to 30 | | | | 100 | | | UC = 114 MPa<br>BD = 2.52 | |
| 161 | | | Hard black COAL; cleat at 5° with core axis. | ■ | | 2 to 6 | /5 | 5° | | 0 | | | | |
| | | | Medium hard carbon bearing MUDSTONE | | | 10<br>2 to 3<br>10 to 25 | | | | 80 | | | | |
| 162 | | | Hard, black COAL; sub-vertical cleat (Galt rider) | ■ | | 23 | | | | 100 | | | | |



| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | silty SANDSTONE | | | | | | UC = 114 MPa<br>BD = 2.52 |
| 161 | | | Hard black COAL; cleat at 5° with core axis. | | 2 to 6 | /S | 5° | 0 | |
| | | | Medium hard carbon bearing MUDSTONE | | 10<br>2 to 3<br>10 to 25 | | | 80 | |
| 162 | | | Hard, black COAL; sub-vertical cleat (Galt rider) | | 23 | | | 100 | |
| | 3 | 100 | COAL | | 10 to 15 | /R | 75° | 70 | UC = 14.5 MPa<br>MC = 9.3% |
| | | | Medium soft, dark brown-grey CARBONACEOUS MUDSTONE; massive | | | /K | 55° | 65 | |
| | | | COAL; massive | | 10 | /S | 55° | | |
| 163 | | | | | 20 | /S | 55° | | |
| | | | Hard, black COAL; cleat at 5° with core axis (Galt Seam) | | 10 | | | 65 | UC = 12.5 MPa<br>UC = 13.0 MPa |
| | | | Medium soft CARB. MUDSTONE | | | | | | |
| 164 | | | argillaceous | | | | | | SD = 98, 79% |
| 165 | | | Medium soft dark browish grey CARB. MUDSTONE | xxx | 20 to 40 | | | 100 | SD = 96, 87%<br>BD = 2.38 |
| | | | Medium hard, dark grey MUDSTONE; massive | | | | | | PI = 27%<br>FS = 1.3% |
| | 4 | 100 | argillaceous COAL | | 5 to 20 | | | 90 | FS = 0.3% |
| | | | CARB. MUDSTONE | | | | | | |
| | | | Medium hard, black, argillaceous COAL; massive | | | | | | SD = 91, 75% |
| 166 | | | Medium hard, dark grey MUDSTONE; carbon bearing with coal laminae on top. | | 40 | | | | SD = 56, 5%<br>PI = 39%<br>UC = 12.6 MPa |
| | | | SILTSTONE | | | | | | |
| | | | Hard, med grey silty SANDSTONE | | | | | | |
| | | | Hard, black COAL; no cleat, slightly argillaceous with depth (Split #2) | | 10 to 40 | | | | UC = 19.1 MPa |
| 167 | | | MUDSTONE | | | | | | |
| | | | argillaceous | | 15 | | | | |
| | | | Medium soft, dark brownish grey CARBONACEOUS MUDSTONE | | 10 to 15 | | | | MC = 13.4% |
| | | | Hard, black COAL; massive (Split #3). | | | | | | |
| | | | carbon brg. MUDSTONE | | | | | | |
| 168 | | | ... grading to CARBONACEOUS MUDSTONE | | | | | | |
| | 5 | 98 | Medium hard, medium greenish grey MUDSTONE | xxx | 10 to 20 | /S<br>/K | 55°<br>55° | 80 | |
| 169 | | | silty | | | /K | 55° | | |
| | | | | | 40 | | | | |
| | | | Hard, black argillaceous COAL; massive. | | 15 | | | | PI = 94% |
| | | | BENTONITE | | | | | | |
| | | | CARB. MUDSTONE | | 5 to 15 | | | | PI = 121%<br>MC = 26.3% |
| | | | BENTONITE | | | | | | |
| 170 | | | (Split #4) | | | | | | |



PI = 94%
PI = 121%
MC = 26.3%
80
100
80
50
100
90
sheer
55°
55°
55°
30°
45°
30°
60°
20°
/S
/K
/K
/K
/S
/S
/S
/S
10
10
20
40
15
5
10
15
10
10
20
5
10
50
10
30
20
xxx
mt
m3
xxx
xxx
xxx
Medium hard, medium greenish grey MUDSTONE
silty
Hard, black argillaceous COAL; massive.
BENTONITE
CARB. MUDSTONE
BENTONITE
(Split #4)
Medium hard, medium grey MUDSTONE with occasional coal interclasts.
SILTSTONE
Medium soft, dark brownish grey CARB. MUDSTONE.
carbon bearing
Medium hard, medium greenish grey argillaceous SILTSTONE, massive.
FAULT CONTACT
CARBONACEOUS MUDSTONE
BENTONITE
Medium hard, medium grey silty MUDSTONE
carbon bearing, non silty
Medium soft CARBONACEOUS MUDSTONE with coal laminae.
End of Borehole
98
5
97
6
169
170
171
172
173
174
175

DRILLING A

Drill Rig - R
Bit - Tungst
Contractor -
Date Drilled
Date Logged
Collar Elevat
Drillhole Ori
Core Barrel
Casing - 152

LEGEND

☒ Core los
m3 Gouge w
xxx Broken o
HHH Broken -
CIB Concretic

FRACTURE

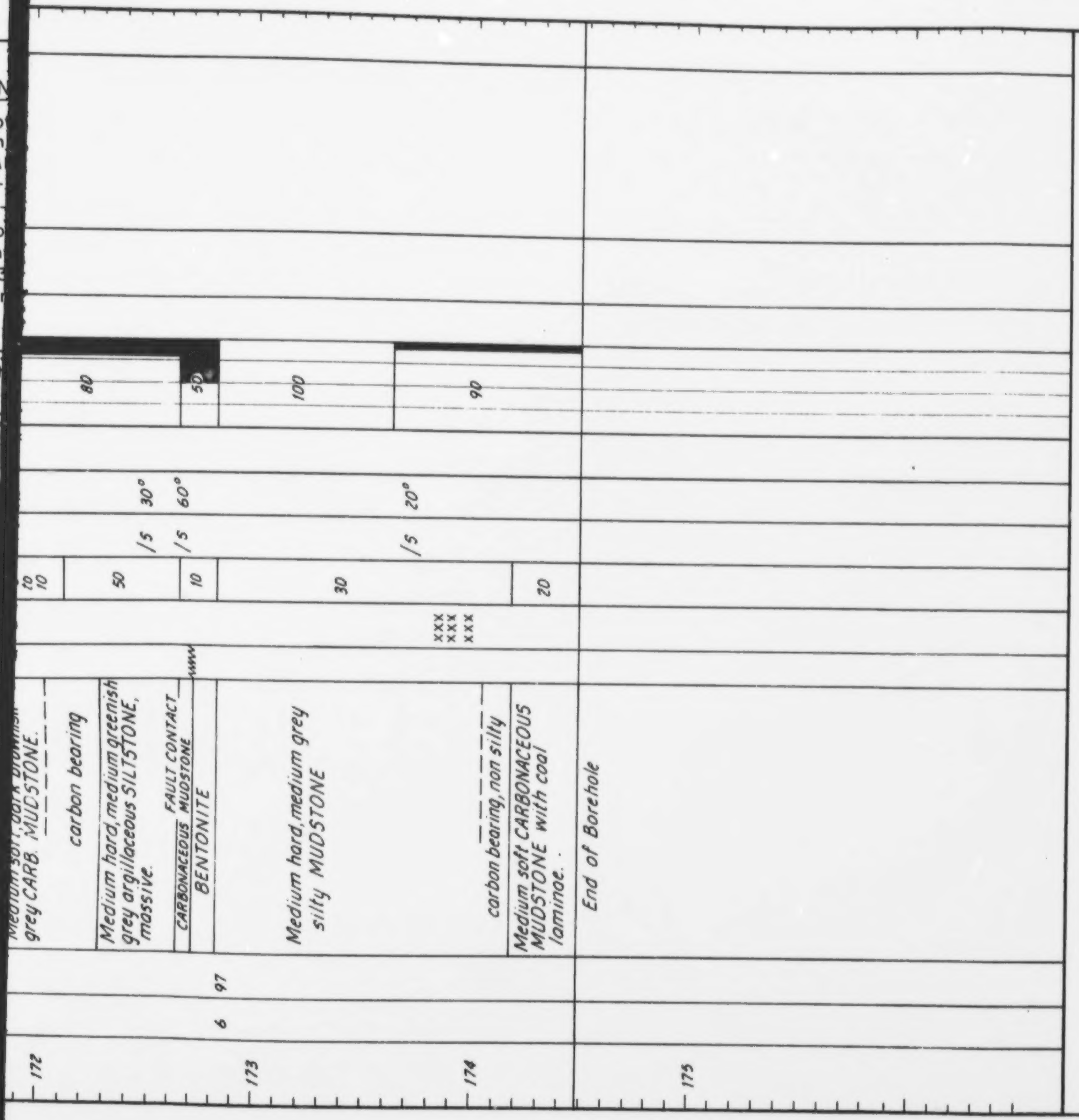
Macro
— Pl
◡ Cu
~ St
〰 Irr

NOTE

1) See also g
in FIGURE

ABBREVIAT

| | |
|---|---|
| B.D. | Bulk D |
| U.C. | Uniaxi |
| F.S. | Free S |
| S.D. | Slake |
| P.I. | Plasti |
| M.C. | Moistu |


80
50
100
90
30°
60°
20°
/5
/5
/5
20
10
50
10
30
20
xxx
xxx
xxx
Medium soft, dark brownish grey CARB. MUDSTONE.
carbon bearing
Medium hard, medium greenish grey argillaceous SILTSTONE, massive.
CARBONACEOUS MUDSTONE
FAULT CONTACT
BENTONITE
Medium hard, medium grey silty MUDSTONE
carbon bearing, non silty
Medium soft CARBONACEOUS MUDSTONE with coal laminae.
End of Borehole
97
6
172
173
174
175

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Golder Associates

## DRILLING AND SURVEY DATA

Drill Rig - Rotary, Ingersoll Rand T.H. 60, Air Flush.
Bit - Tungsten Carbide, 76mm x 140mm.
Contractor - Alberta Southern Exploration Drilling Ltd.
Date Drilled - Feb. 18 , 1983 by B. Bierman.
Date Logged - Feb. 18 , 1983 by W. Claeys.
Collar Elevation: 959.86 m , Location: 5 532 268.0 m N
Drillhole Orientation - Vertical. 81 151.5 m E
Core Barrel - 305mm Christensen.
Casing - 152mm, hammered to 106.4 m and abandoned.

## LEGEND

⊠ Core loss - assumed to have occured at top of run.
mm3 Gouge with thickness in millimeters, t = trace.
xxx Broken or Brecciated.
HHH Broken - mainly horizontally.
CIB Concretionary Ironstone Band.

## FRACTURE ROUGHNESS

| Macro | Micro |
|---|---|
| — Planar | K Slick |
| ◡ Curve | S Smooth |
| ∼ Stepped | R Rough |
| 〰 Irregular | |

## NOTE

1) See also geophysical logs by Roke and core photographs in FIGURE 5-9

## ABBREVIATIONS

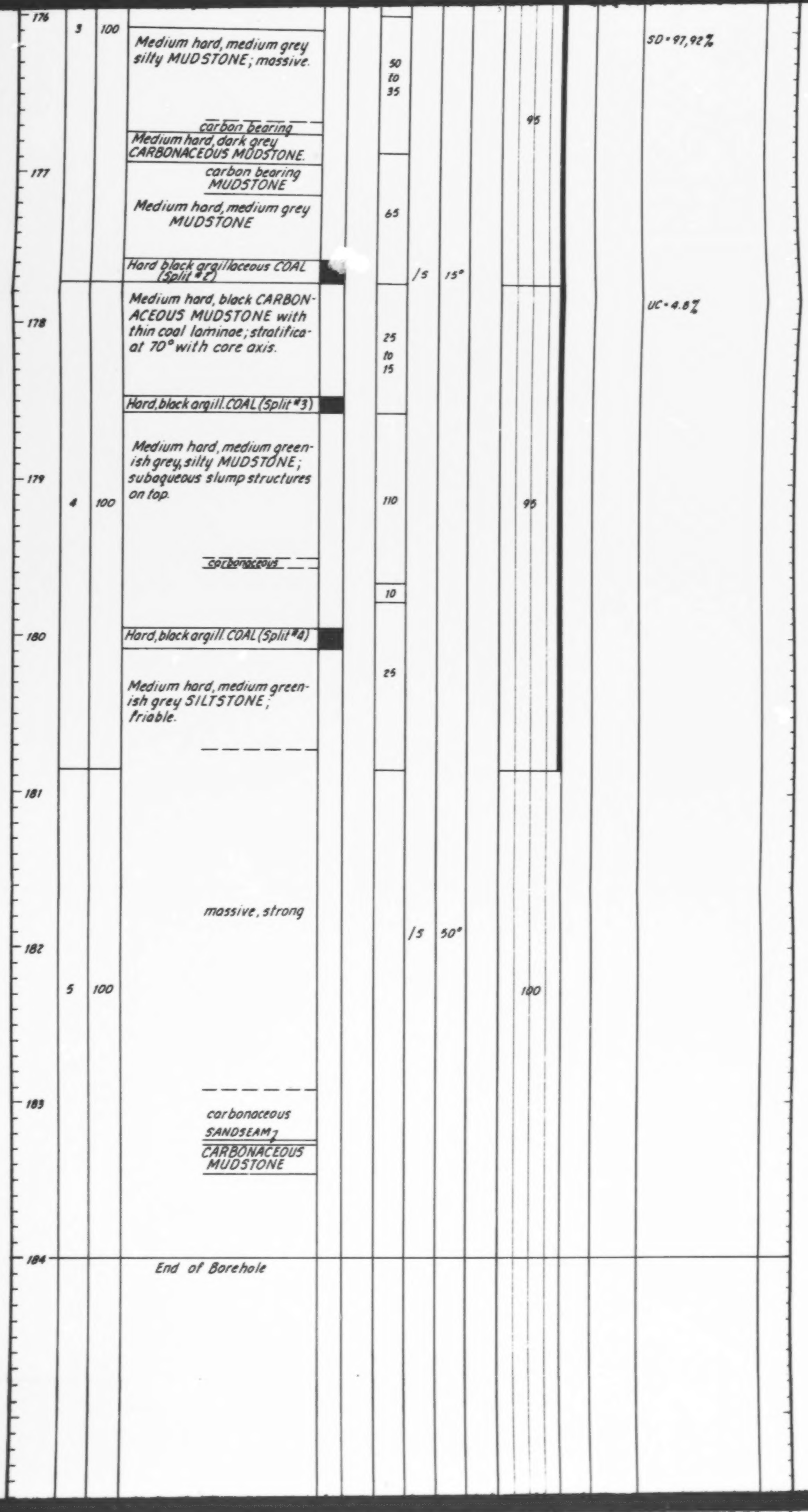
| | |
|---|---|
| B.D. | Bulk Density |
| U.C. | Uniaxial Compressive Strength |
| F.S. | Free Swell |
| S.D. | Slake Durability |
| P.I. | Plasticity Index |
| M.C. | Moisture Content |

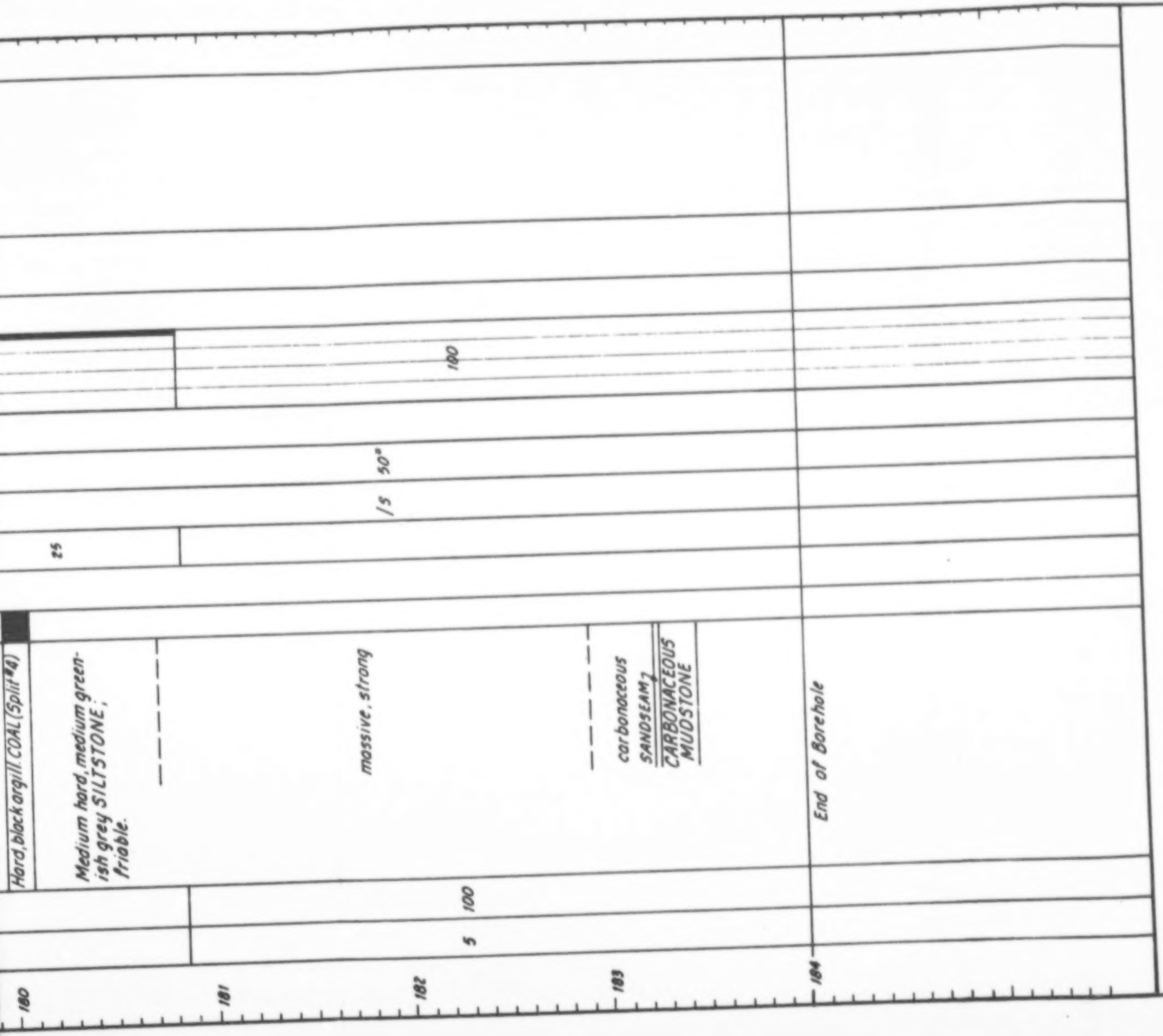
FIGURE 5 - 2

PRECAMBRIAN SHIELD RESOURCES LIMITED
COAL DIVISION
PICTURE BUTTE COAL PROJECT
A TECHNICAL ASSESSMENT OF PICTURE BUTTE
1983

**GEOTECHNICAL CORE LOG**
**DRILLHOLE PB 83-1**

| Depth m | Core Run No. | Recov. % | Lithologic Description | Log | Gouge (mm) Broken Zones | Bdg. Brk. Int. (cm) | Fractures: Roughness | Fractures: Dip | Fractures: Notes | Rock Quality Designation % (25 50 75) | Depth No. | Comp. Strength MPa | Slake Durability Elastic Modulus | Rock Class |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 168 | | | | | | | | | | | | | | |
| | | | Hard, black COAL; massive; cleat at 15° (rider). | ■ | | 40 | | | | | | | | |
| 169 | | | Med. soft CARB. MUDSTONE | | | | | | | | | | | |
| | | | | | | 20 | | | | | | | | |
| | | | medium soft | | | 2 | | | | | | | | |
| 170 | 1 | 100 | Medium hard, dark grey silty MUDSTONE | | | 30 to 40 | | | | 97 | | | | |
| 171 | | | | | | | | | | | | | | |
| | | | Hard, indurated concretionary IRONSTONE | | | | | | | | | | UC = 83.2 MPa<br>BD = 3.22 | |
| | | | argillaceous SILTSTONE | | | | | | | | | | | |
| 172 | | | Medium hard, dark grey MUDSTONE; trace of silt, massive, stratification at 85° with core axis. | | | 15 to 25 | | | | | | | MC = 8.9% | |
| | | | siltstone lenses | | | | | | | | | | | |
| | | | | | | 50 | | | | | | | UC = 7.6 MPa<br>MC = 8.4% | |
| 173 | 2 | 100 | Hard, black COAL; cleat at 15° with core axis (@75°) (Galt rider) | ■ | | | /s | 15° | | 82 | | | | |
| | | | | | | | | | | | | | SD = 88, 70% | |
| | | | Medium hard, brownish black CARBONACEOUS MUDSTONE; massive. | | | 25 | | | | | | | | |
| | | | COAL | ■ | | | | | | | | | UC = 13.6 MPa<br>SD = 84, 22% | |
| 174 | | | | | | 10 | | | | | | | | |
| | | | COAL | ■ | | 25 | | | | | | | UC = 13.5 MPa<br>MC = 8.7% | |
| | | | Hard, black COAL; cleat at 15° (Galt Seam) | ■ | | | /s | 15° | | | | | | |
| | | | argillaceous | ■ | | | | | | | | | | |
| 175 | | | | ■ | | 70 to 90 | /s | 10° | | 70 | | | SD = 47, 24%<br>SD = 98, 92% | |
| | | | Medium soft, brownish black CARBONACEOUS MUDSTONE. | | | | (K | 60° | | | | | | |
| 176 | 3 | 100 | Medium hard, medium grey silty MUDSTONE; massive. | | | 50 to 35 | | | | | | | SD = 97, 92% | |


176
177
178
179
180
181
182
183
184
3
100
4
100
5
100
Medium hard, medium grey silty MUDSTONE; massive.
carbon bearing
Medium hard, dark grey CARBONACEOUS MUDSTONE.
carbon bearing MUDSTONE
Medium hard, medium grey MUDSTONE
Hard black argillaceous COAL (Split #2)
Medium hard, black CARBONACEOUS MUDSTONE with thin coal laminae; stratifica- at 70° with core axis.
Hard, black argill. COAL (Split #3)
Medium hard, medium greenish grey, silty MUDSTONE; subaqueous slump structures on top.
carbonaceous
Hard, black argill. COAL (Split #4)
Medium hard, medium greenish grey SILTSTONE; friable.
massive, strong
carbonaceous
SANDSEAM
CARBONACEOUS MUDSTONE
End of Borehole
50 to 35
65
25 to 15
110
10
25
/s 15°
/s 50°
95
95
100
SD = 97,92%
UC = 4.8%


100
50°
/S
25
Hard, black argill. COAL (Split #4)
Medium hard, medium green-ish grey SILTSTONE; friable.
massive, strong
carbonaceous
SANDSEAM
CARBONACEOUS MUDSTONE
End of Borehole
100
5
180
181
182
183
184

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## DRILLING AND SURVEY DATA

Drill Rig - Rotary, Ingersoll Rand T.H. 60, Air Flush.
Bit - Tungsten Carbide, 76mm x 140mm.
Contractor - Alberta Southern Exploration Drilling Ltd.
Date Drilled - Feb. 20, 1983 by B. Bierman.
Date Logged - Feb. 20, 1983 by W. Claeys.
Collar Elevation: 951.84m, Location: 5 531 442.0 mN
79 512.5 mE
Drillhole Orientation - Vertical.
Core Barrel - 305mm Christensen.
Casing - 152mm, hammered to 67.4m and abandoned.

## LEGEND

☒ Core loss - assumed to have occured at top of run.
m3 Gouge with thickness in millimeters, t = trace.
xxx Broken or Brecciated.
HHH Broken - mainly horizontally.
CIB Concretionary Ironstone Band.

## FRACTURE ROUGHNESS

| Macro | Micro |
|---|---|
| — Planar | K Slick |
| ◡ Curve | S Smooth |
| ∼ Stepped | R Rough |
| ∿ Irregular | |

## NOTE

1) See also geophysical logs by Roke and core photographs in FIGURE 5-10

## ABBREVIATIONS

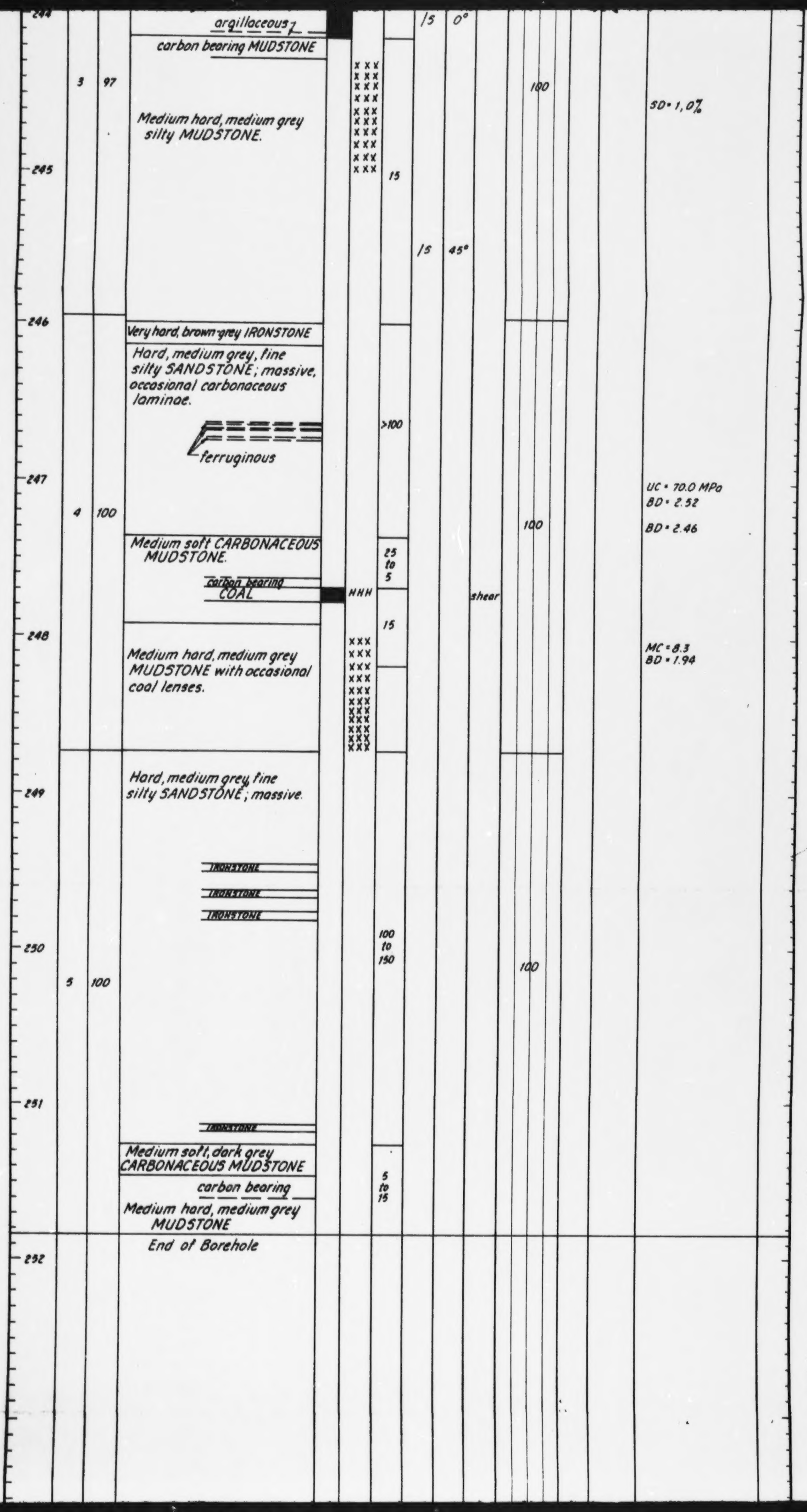
| | |
|---|---|
| B.D. | Bulk Density |
| U.C. | Uniaxial Compressive Strength |
| F.S. | Free Swell |
| S.D. | Slake Durability |
| M.C. | Moisture Content |

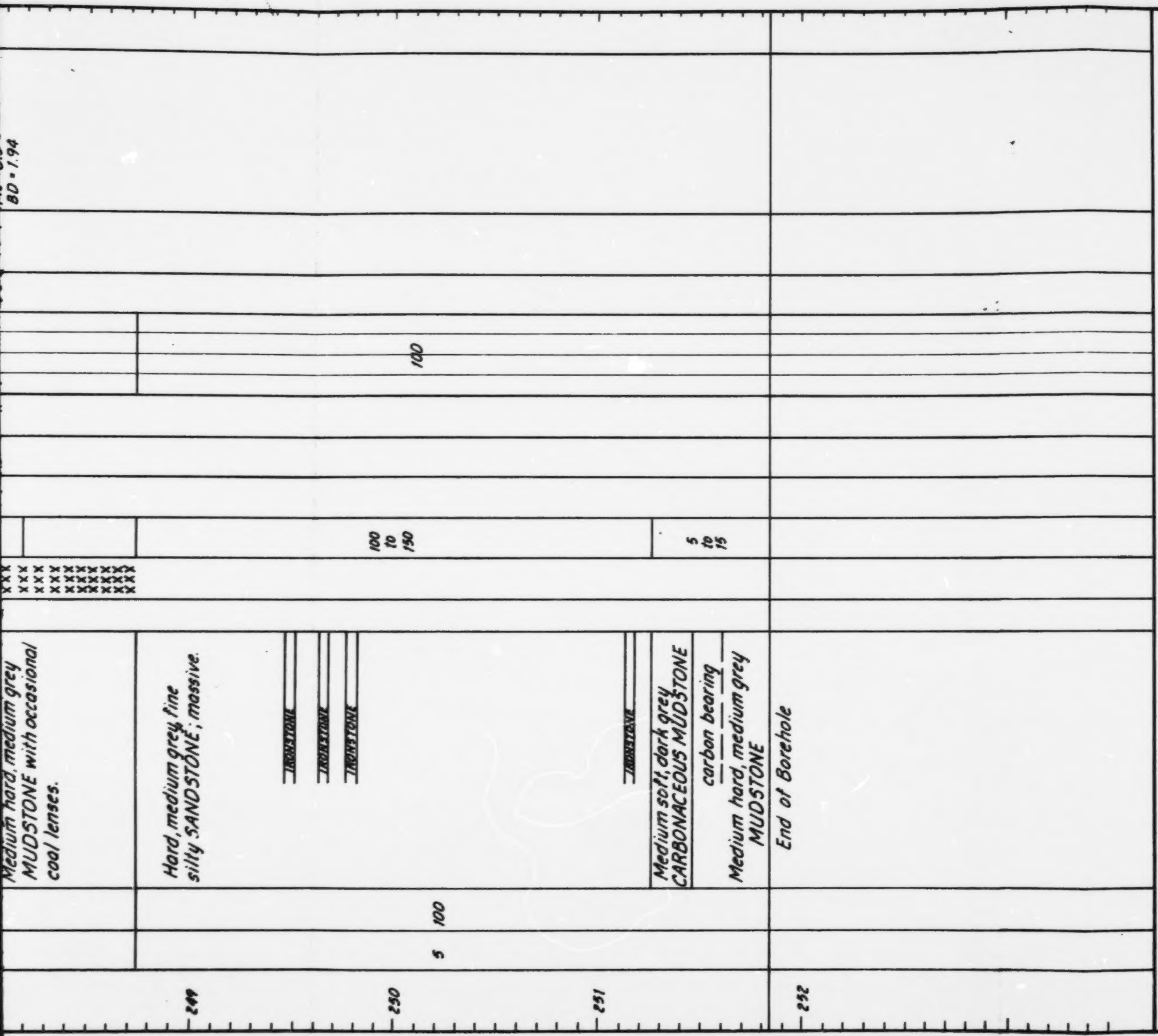
FIGURE 5 - 3

PRECAMBRIAN SHIELD RESOURCES LIMITED
COAL DIVISION
PICTURE BUTTE COAL PROJECT
A TECHNICAL ASSESSMENT OF PICTURE BUTTE
1983
GEOTECHNICAL CORE LOG
DRILLHOLE PB 83-2

PA88-062

| Depth m | Core Run No. | Recov. % | Lithologic Description | Log | Structure: Gouge (mm) Broken Zones | Structure: Bdg. Brk. Int. (cm) | Structure: Fractures Roughness | Structure: Fractures Dip | Structure: Fractures Notes | Rock Quality Designation % (25 50 75) | Test Results & Notes: Depth No. | Test Results & Notes: Comp. Strength MPa | Test Results & Notes: Slake Durability Elastic Modulus | Test Results & Notes: Rock Class |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 236 | | | | | | | | | | | | | | |
| | | | Hard, black COAL; no visible cleat (rider). | ■ | | | | | | | | | | |
| 237 | | | CARBONACEOUS MUDSTONE | | | 15 | | | | | | | | |
| | | | Medium hard, dark grey MUDSTONE; massive, carbon bearing. | | | 185 | | | | | | | | |
| 238 | 1 | 90 | | | | | | | | | | | | |
| | | | with occasional calcareous stringers | | | | /5 | 35° | | | | | | |
| 239 | | | indurated IRONSTONE | | | 15 | | | | | | | UC = 47.6 MPa<br>BD = 3.06 | |
| | | | Medium hard, dark grey MUDSTONE | | | 15 to 30 | | | | 100 | | | | |
| 240 | | | Hard, black COAL (Galt rider) | ■ | | 10 to 15 | /5 | 45° | | | | | | |
| | | | carb. SHALE | | | 3 to 10 | | | | | | | | |
| | | | Medium hard, dark grey carbon bearing MUDSTONE | | | 30 to 50 | | | | | | | | |
| 241 | | | carbonaceous | | | | | | | | | | UC = 28.7<br>BD = 2.33 | |
| | 2 | 92 | Hard, black COAL (Galt Seam) | ■ | | 15 to 50 | /5 | 0° | | 100 | | | UC = 9.2 MPa<br>SD = 96, 90%<br>UC = 20.0 MPa | |
| 242 | | | | | | | | | | | | | | |
| | | | BENTONITIC MUDSTONE | | | 2 to 3 | | | | 0 | | | | |
| | | | Fissile carb. brg. MUDSTONE | | | | | | | | | | | |
| | | | IRONSTONE | | | | | | | | | | | |
| | | | Medium hard, medium grey MUDSTONE; massive. | | | >50 | | | | 100 | | | | |
| 243 | | | silty laminae | | | | | | | | | | | |
| | | | silty | | | 20 | | | | | | | | |
| | | | Hard, black COAL; massive; subvertical cleat (Split #2). | ■ | | 10 to 20 | | | | | | | BD = 1.51<br>SD = 75, 45 | |
| 244 | | | argillaceous | | | | /5 | 0° | | | | | | |
| | | | carbon bearing MUDSTONE | | | | | | | | | | | |
| | 3 | 97 | | | x x x<br>x x x<br>x x x<br>x x x | | | | | 100 | | | SD = 1, 0% | |


244
245
246
247
248
249
250
251
252
3
97
4
100
5
100
argillaceous
carbon bearing MUDSTONE
Medium hard, medium grey silty MUDSTONE.
Very hard, brown-grey IRONSTONE
Hard, medium grey, fine silty SANDSTONE; massive, occasional carbonaceous laminae.
ferruginous
Medium soft CARBONACEOUS MUDSTONE.
carbon bearing
COAL
Medium hard, medium grey MUDSTONE with occasional coal lenses.
Hard, medium grey, fine silty SANDSTONE; massive.
IRONSTONE
IRONSTONE
IRONSTONE
IRONSTONE
Medium soft, dark grey CARBONACEOUS MUDSTONE
carbon bearing
Medium hard, medium grey MUDSTONE
End of Borehole
HHH
15
>100
25 to 5
15
100 to 150
5 to 15
/5
0°
/5
45°
shear
100
100
100
SD = 1,0%
UC = 70.0 MPa
BD = 2.52
BD = 2.46
MC = 8.3
BD = 1.94


BD = 1.94
100
100 to 150
5 to 15
Medium hard, medium grey MUDSTONE with occasional coal lenses.
Hard, medium grey fine silty SANDSTONE; massive.
IRONSTONE
IRONSTONE
IRONSTONE
IRONSTONE
Medium soft, dark grey CARBONACEOUS MUDSTONE
carbon bearing
Medium hard, medium grey MUDSTONE
End of Borehole
100
5
249
250
251
252

**Associated Mining Consultants Ltd.**
**Golder Associates**

## DRILLING AND SURVEY DATA

Drill Rig - Rotary, Ingersoll Rand T.H. 60, Air Flush.
Bit - Tungsten Carbide, 76 mm x 140 mm.
Contractor - Alberta Southern Exploration Drilling Ltd.
Date Drilled - Feb. 23, 1983 by B. Bierman.
Date Logged - Feb. 23, 1983 by W. Claeys.
Collar Elevation: 988.75 m, Location: 5 529 734.5 mN
Drillhole Orientation - Vertical. 76 259.5 mE
Core Barrel - 305 mm Christensen.
Casing - 152 mm, hammered to 30.5 m and abandoned.

## LEGEND

- ☒ Core loss - assumed to have occured at top of run.
- m3 Gouge with thickness in millimeters, t = trace.
- xxx Broken or Brecciated.
- HHH Broken - mainly horizontally.
- CIB Concretionary Ironstone Band.

## FRACTURE ROUGHNESS

| Macro | Micro |
|---|---|
| ⌒ Planar | K Slick |
| ◡ Curve | S Smooth |
| ∼ Stepped | R Rough |
| 〰 Irregular | |

## NOTE

1) See also geophysical logs by Roke and core photographs in FIGURE 5-11

## ABBREVIATIONS

| | |
|---|---|
| B.D. | Bulk Density |
| U.C. | Uniaxial Compressive Strength |
| F.S. | Free Swell |
| S.D. | Slake Durability |
| M.C. | Moisture Content |

FIGURE 5 - 4

PRECAMBRIAN SHIELD RESOURCES LIMITED
COAL DIVISION
PICTURE BUTTE COAL PROJECT
A TECHNICAL ASSESSMENT OF PICTURE BUTTE
1983

**GEOTECHNICAL CORE LOG**
**DRILLHOLE PB 83-3**

PA88-063

Depth m
Core Run No.
Recov. %
Lithologic Description
Log
Structure
Fractures
Rock Quality Designation %
Test Results & Notes
Comp. Strength MPa
Slake Durability
Elastic Modulus
Rock Class
Hard, black COAL; sub-vertical cleat, 2cm apart (rider)
CARBONACEOUS MUDSTONE
Medium hard, dark grey MUDSTONE; massive.
occasional calcareous fragments
Hard, indurated IRONSTONE
medium grey
Hard, black COAL (Galt rider)
Medium hard, dark grey MUDSTONE; massive.
carbon bearing
Hard, black COAL; cleat at 5° with core axis (Galt Seam)
Medium hard, brown black CARBONACEOUS MUDSTONE
carbon bearing with occasional coal lenses
Medium hard, dark grey MUDSTONE
IRONSTONE bands
occasional calcareous laminae
Medium hard, brown black CARBONACEOUS MUDSTONE
SILTSTONE
carbon bearing with occasional coal lenses
Medium hard, dark grey MUDSTONE
IRONSTONE bands
occasional calcareous laminae
carbon bearing with occ. coal laminae
Hard, black COAL; massive
Med. soft CARB. MUDSTONE
Medium hard, medium greenish grey MUDSTONE; massive.
Hard, highly indurated IRONSTONE
Hard, medium grey silty SANDSTONE
Hard, black COAL; massive argillaceous MUDSTONE
Medium to dark grey, argillaceous SILTSTONE; finely laminated, with fine carbonaceous laminae.
carbon bearing
Medium hard, dark greenish grey silty MUDSTONE
COAL
lighter
Hard, medium grey silty SANDSTONE
Hard, black COAL; massive argillaceous MUDSTONE
Medium to dark grey, argillaceous SILTSTONE; finely laminated, with fine carbonaceous laminae.
carbon bearing
Medium hard, dark greenish grey silty MUDSTONE
COAL
lighter
End of Borehole
UC-14.4 MPa SD-3.17
UC-26.4 MPa SD-79, 10%
SD-95, 83%
UC-13.2 MPa
SD-77, 31%
UC-16.0 MPa SD-96, 83%
SD-77, 31%
UC-16.0 MPa SD-96, 83%
UC-20.7 MPa
see photograph in Fig.
195
196
197
198
199
200
201
202
203
204
205
206
207
208
209
210
211
212

Associated Mining Consultants Ltd.
Golder Associates

## DRILLING AND SURVEY DATA

Drill Rig - Rotary, Ingersoll Rand T.H. 60, Air Flush.
Bit - Tungsten Carbide, 76mm x 140mm.
Contractor - Alberta Southern Exploration Drilling Ltd.
Date Drilled - Feb.26 , 1983 by B. Bierman.
Date Logged - Feb.26 , 1983 by W. Claeys.
Collar Elevation: 967.81m , Location: 5 526 545.5 mN
Drillhole Orientation - Vertical. 76 327.0 mE
Core Barrel - 305mm Christensen.
Casing - 152 mm, hammered to 30.3 m and abandoned.

## LEGEND

⌧ Core loss - assumed to have occured at top of run.
m3 Gouge with thickness in millimeters, t = trace.
xxx Broken or Brecciated.
HHH Broken - mainly horizontally.
CIB Concretionary Ironstone Band.

## FRACTURE ROUGHNESS

| Macro | Micro |
|---|---|
| Planar | K Slick |
| Curve | S Smooth |
| Stepped | R Rough |
| Irregular | |

## NOTE

1) See also geophysical logs by Roke and core photographs in FIGURE 5-12

## ABBREVIATIONS

| | |
|---|---|
| B.D. | Bulk Density |
| U.C. | Uniaxial Compressive Strength |
| F.S. | Free Swell |
| S.D. | Slake Durability |

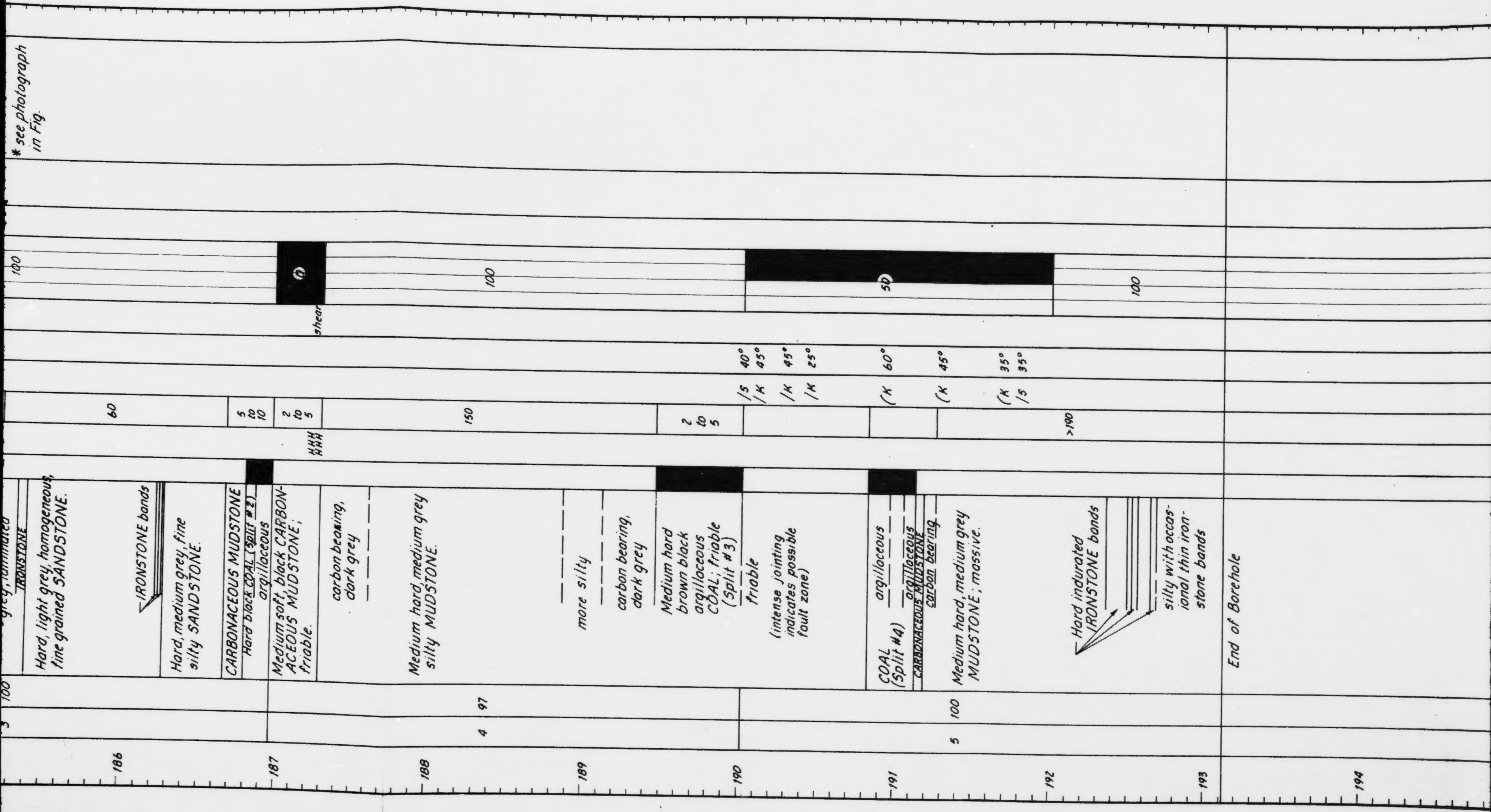
FIGURE 5 - 5

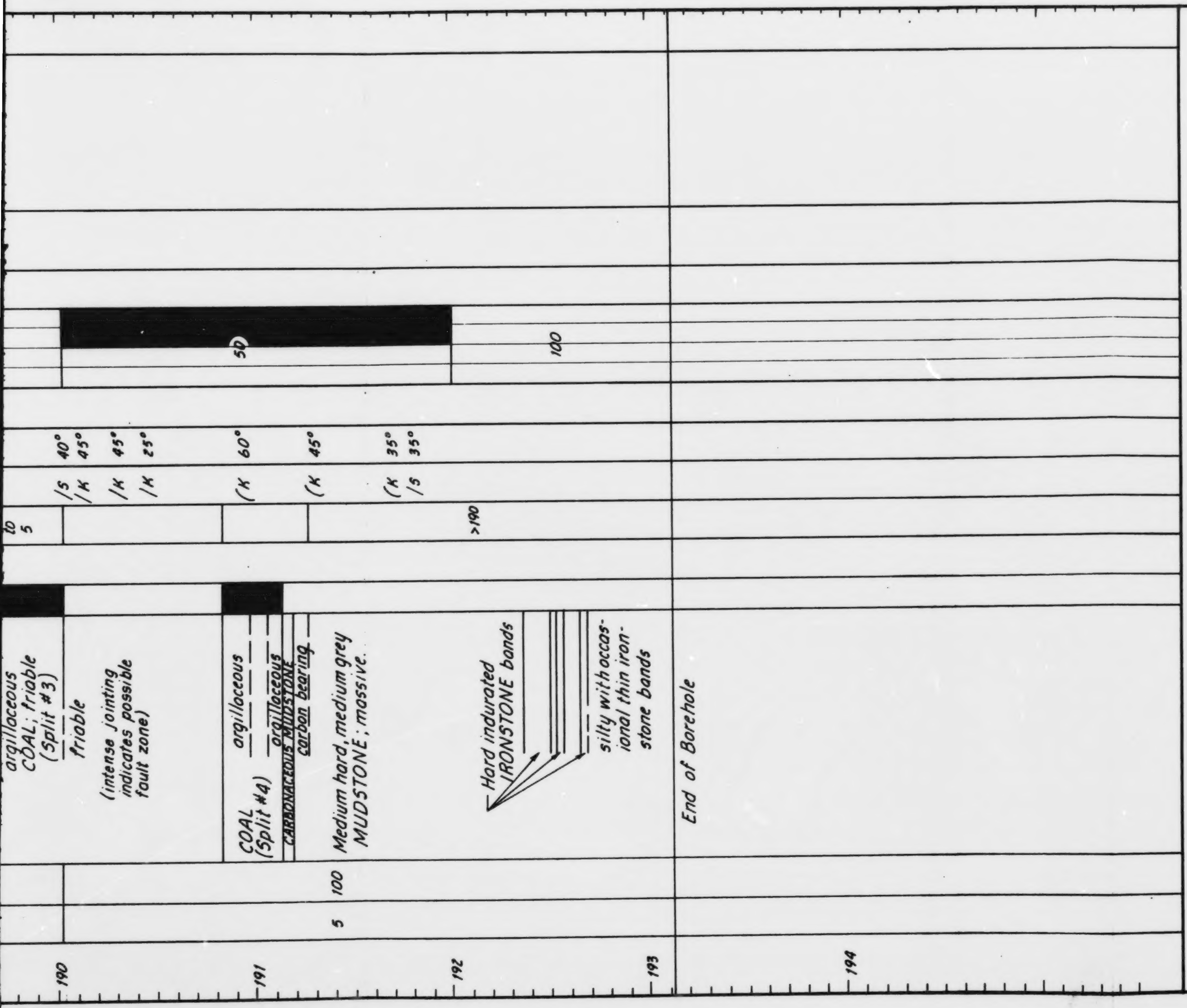
PRECAMBRIAN SHIELD RESOURCES LIMITED
COAL DIVISION
PICTURE BUTTE COAL PROJECT
A TECHNICAL ASSESSMENT OF PICTURE BUTTE
1983

GEOTECHNICAL CORE LOG
DRILLHOLE PB 83-4

PA88-064

| Depth m | Core Run No. | Recov. % | Lithologic Description | Log | Gouge (mm) Broken Zones | Bdg. Brk. Int. (cm) | Fractures Roughness | Fractures Dip | Fractures Notes | Rock Quality Designation % (25 50 75) | Depth No. | Comp. Strength MPa | Slake Durability Elastic Modulus | Rock Class |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 177 | | | | | | | | | | | | | | |
| | | | Medium hard, dark grey MUDSTONE | | | >100 | | | | | | | | |
| | | | — — — — | | HHH | | /5 | 45° | shear | | | | | |
| 178 | | | slightly silty | | | | /5<br>/5 | 60°<br>60° | | | | | | |
| | | | — — — — | | | | | | | | | | | |
| | | | occasional calcareous stringers & lenses; bedding at 5° with core axis. | | | | | | | | | | | |
| 179 | 1 | 97 | | | | | | | | 95 | | | | |
| | | | | | | | /P | 40° | | | | | | |
| | | | carbonaceous | | | | | | | | | | | |
| | | | Hard black COAL (Galt rider) | ■ | | | | | | | | | | |
| 180 | | | Medium hard, dark grey MUDSTONE; massive | | | | | | | | | | | |
| | | | — ? — ? — ? — ? — | | | | | | | | | | | |
| 181 | | | carbon bearing | | | | | | | | | | UC = 14.5 MPa | |
| | | | | | | | /5 | 15° | | | | | | |
| | | | Hard, black COAL; massive; cleat at 15° with core axis, but poorly developed. (Galt Seam) | ■ | | | | | | 100 | | | | |
| 182 | | | | | | | /5<br>/5 | 15°<br>15° | | 50 | | | | |
| | 2 | 100 | | | | | | | | | | | | |
| | | | Medium soft, brownish black CARBONACEOUS MUDSTONE with coal laminae. | | | 30 | | | | | | | SD = 94, 67% | |
| 183 | | | Medium hard, medium grey, argillaceous SILTSTONE; massive. | | | | | | | 100 | | | UC = 31.3 MPa<br>SD = 93, 84% | |
| | | | — — — —<br>slightly laminated | | | | | | | | | | | |
| | | | Hard, medium grey, very fine grained silty SANDSTONE; massive. | | | | | | | | | | UC = 44.0 MPa<br>BD = 2.44<br>SD = 94, 89% | |
| 184 | | | | | | 180 | | | | | | | | |
| | | | IRONSTONE | | | | | | | | | | | |
| | | | more silty<br>— — — — | | | | | | | | | | | |
| 185 | | | bentonitic matrix | | | | | | | | | | | |
| | 3 | 100 | more silty, dark grey, laminated | | | | | | | 100 | | | * see photograph in Fig. | |
| | | | IRONSTONE | | | | | | | | | | | |
| | | | Hard, light grey, homogeneous, fine grained SANDSTONE. | | | | | | | | | | | |


* see photograph in Fig.
100
100
50
100
shear
40°
45°
45°
25°
60°
45°
35°
35°
/S
/K
/K
/K
(K
(K
(K
/S
60
5 to 10
2 to 5
150
2 to 5
>190
HHH HHH
grey, laminated
IRONSTONE
Hard, light grey, homogeneous, fine grained SANDSTONE.
IRONSTONE bands
Hard, medium grey, fine silty SANDSTONE.
CARBONACEOUS MUDSTONE
Hard black COAL (Split #2)
argillaceous
Medium soft, black CARBONACEOUS MUDSTONE; friable.
carbon bearing, dark grey
Medium hard, medium grey silty MUDSTONE.
more silty
carbon bearing, dark grey
Medium hard brown black argillaceous COAL; friable (Split #3)
friable
(intense jointing indicates possible fault zone)
COAL (Split #4)
argillaceous
argillaceous
CARBONACEOUS MUDSTONE
carbon bearing
Medium hard, medium grey MUDSTONE; massive.
Hard indurated IRONSTONE bands
silty with occasional thin ironstone bands
End of Borehole
100
97
100
5
4
5
186
187
188
189
190
191
192
193
194



**Associated Mining Consultants Ltd.**
**Golder Associates**

## DRILLING AND SURVEY DATA

Drill Rig - Rotary, Ingersoll Rand T.H. 60, Air Flush.
Bit - Tungsten Carbide, 76mm x 140mm.
Contractor - Alberta Southern Exploration Drilling Ltd.
Date Drilled - Feb.28 , 1983 by B. Bierman.
Date Logged - Feb.28 , 1983 by W. Claeys.
Collar Elevation: 951.27 m , Location: 5 524 917.0 mN
Drillhole Orientation - Vertical. 78 163.5 mE
Core Barrel - 305mm Christensen.
Casing - 152 mm, hammered to 48.5m and abandoned.

## LEGEND

☒ Core loss - assumed to have occured at top of run.
m3 Gouge with thickness in millimeters, t = trace.
xxx Broken or Brecciated.
HHH Broken - mainly horizontally.
CIB Concretionary Ironstone Band.

## FRACTURE ROUGHNESS

| Macro | Micro |
|---|---|
| — Planar | K Slick |
| ◡ Curve | S Smooth |
| ∼ Stepped | R Rough |
| 〰 Irregular | |

## NOTE

1) See also geophysical logs by Roke and core photographs in FIGURE 5-13

## ABBREVIATIONS

| | |
|---|---|
| B.D. | Bulk Density |
| U.C. | Uniaxial Compressive Strength |
| F.S. | Free Swell |
| S.D. | Slake Durability |

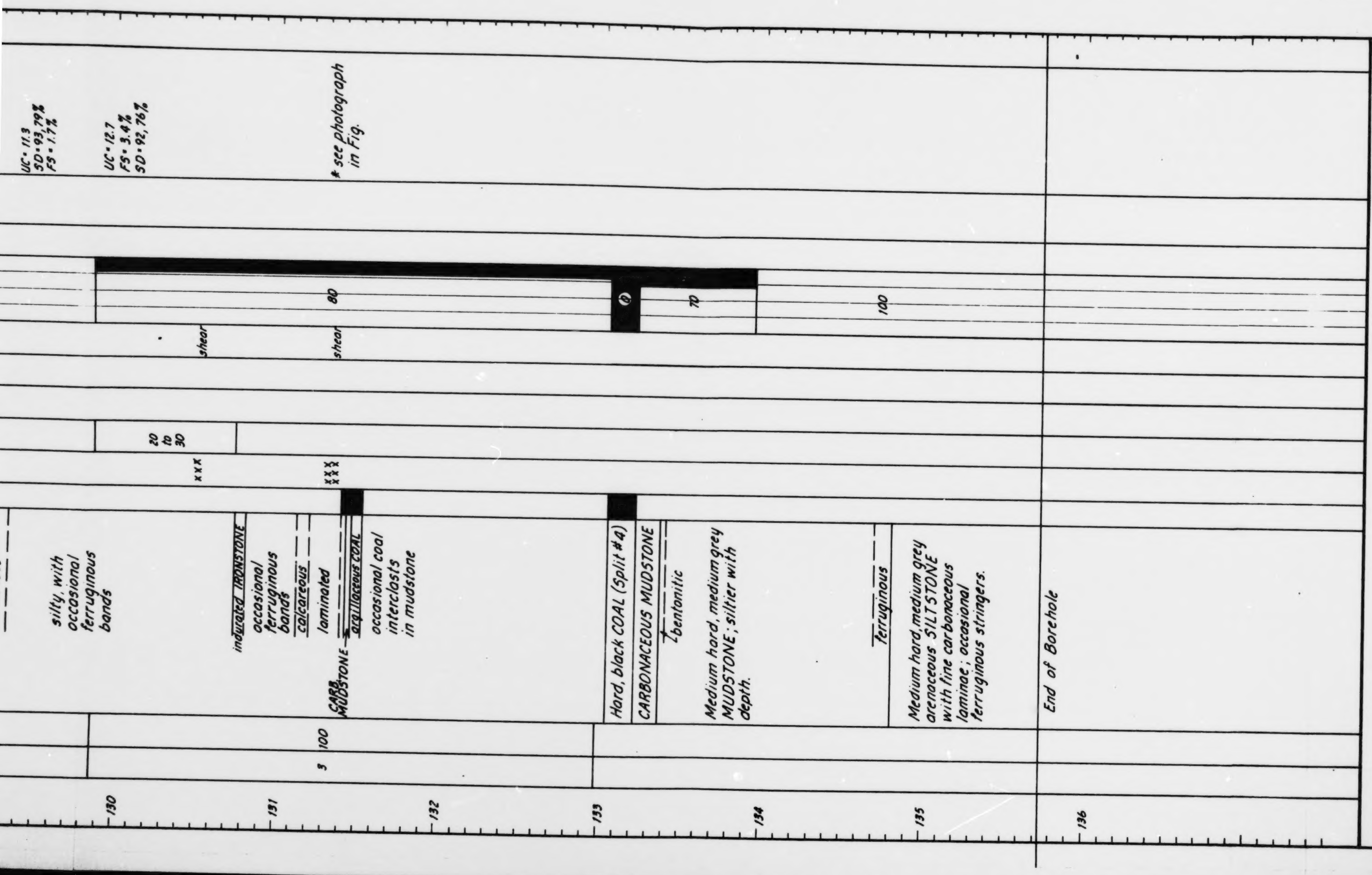
FIGURE 5-6

PRECAMBRIAN SHIELD RESOURCES LIMITED
COAL DIVISION
PICTURE BUTTE COAL PROJECT
A TECHNICAL ASSESSMENT OF PICTURE BUTTE
1983

**GEOTECHNICAL CORE LOG**
**DRILLHOLE P.B 83-5**

PA98-065

| Depth m | Core Run No. | Recov. % | Lithologic Description | Log | Gouge (mm) Broken Zones | Bdg. Brk. Int. (cm) | Fractures Roughness | Fractures Dip | Fractures Notes | Rock Quality Designation % (25 50 75) | Depth No. | Comp. Strength MPa | Slake Durability Elastic Modulus | Rock Class |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 123 | | | | | | | | | | | | | | |
| 124 | | | Medium hard, dark grey silty MUDSTONE; massive. | | | 40 to 60 | | | | | | | | |
| 125 | 1 | 100 | hard, indurated, ferruginous | | | | | | | 95 | | | | |
| | | | calcareous stringers | | | 20 | | | | | | | | |
| 126 | | | Hard, black COAL (Galt rider) | | | | | | | | | | | |
| | | | CARBONACEOUS MUDSTONE with coal laminae. | | | | | | | | | | | |
| | | | Medium hard, dark grey carbon bearing MUDSTONE; massive. | | | 15 to 20 | | | | | | | | |
| 127 | | | Hard, black COAL; massive, poorly dev'd cleat (Galt Seam) | | | 60 | /R | 5° | | | | | | |
| | | | CARB. MUDSTONE parting | | | | | | | | | | | |
| | | | CARB. MUDSTONE ptg. | | | | | | | | | | | |
| 128 | 2 | 100 | argillaceous | | | | | | | 100 | | | PI = 78.5%<br>* see photograph in Fig.<br>SD = 91, 58% | |
| | | | Medium soft, brownish black CARBONACEOUS MUDSTONE. | | | | | | | | | | | |
| | | | Medium hard, medium grey MUDSTONE | | | 30 to 40 | | | | | | | | |
| 129 | | | carbon bearing | | | | (K | 60° | | | | | | |
| | | | occasional coal lenses | | | | | | | | | | UC = 11.3<br>SD = 93,79%<br>FS = 1.7% | |
| | | | silty, with occasional ferruginous bands | | | | | | | | | | | |
| 130 | | | | | xxx | 20 to 30 | | | shear | | | | UC = 12.7<br>FS = 3.4%<br>SD = 92, 76% | |
| | | | indurated IRONSTONE | | | | | | | | | | | |
| 131 | | | occasional ferruginous bands | | | | | | | | | | | |
| | | | calcareous | | | | | | | | | | | |
| | | | occasional | | | | | | | | | | | |


UC - 11.3
SD - 93,79%
FS - 1.7%
UC - 12.7
FS - 3.4%
SD - 92,76%
* see photograph in Fig.
80
0
70
100
shear
shear
20 to 30
xxx
xxx
xxx
silty, with occasional ferruginous bands
indurated IRONSTONE
occasional ferruginous bands
calcareous
laminated
CARB. MUDSTONE
argillaceous COAL
occasional coal interclasts in mudstone
Hard, black COAL (Split #4)
CARBONACEOUS MUDSTONE
bentonitic
Medium hard, medium grey MUDSTONE; siltier with depth.
ferruginous
Medium hard, medium grey arenaceous SILTSTONE with fine carbonaceous laminae; occasional ferruginous stringers.
End of Borehole
100
5
130
131
132
133
134
135
136

DRILLING AN

Drill Rig - Ro
Bit - Tungsten
Contractor - A
Date Drilled -
Date Logged
Collar Elevatio
Drillhole Orien
Core Barrel -
Casing - 152 m

LEGEND

⊠ Core loss
m3 Gouge wit
xxx Broken or
HHH Broken - m
CIB Concretion

FRACTURE R

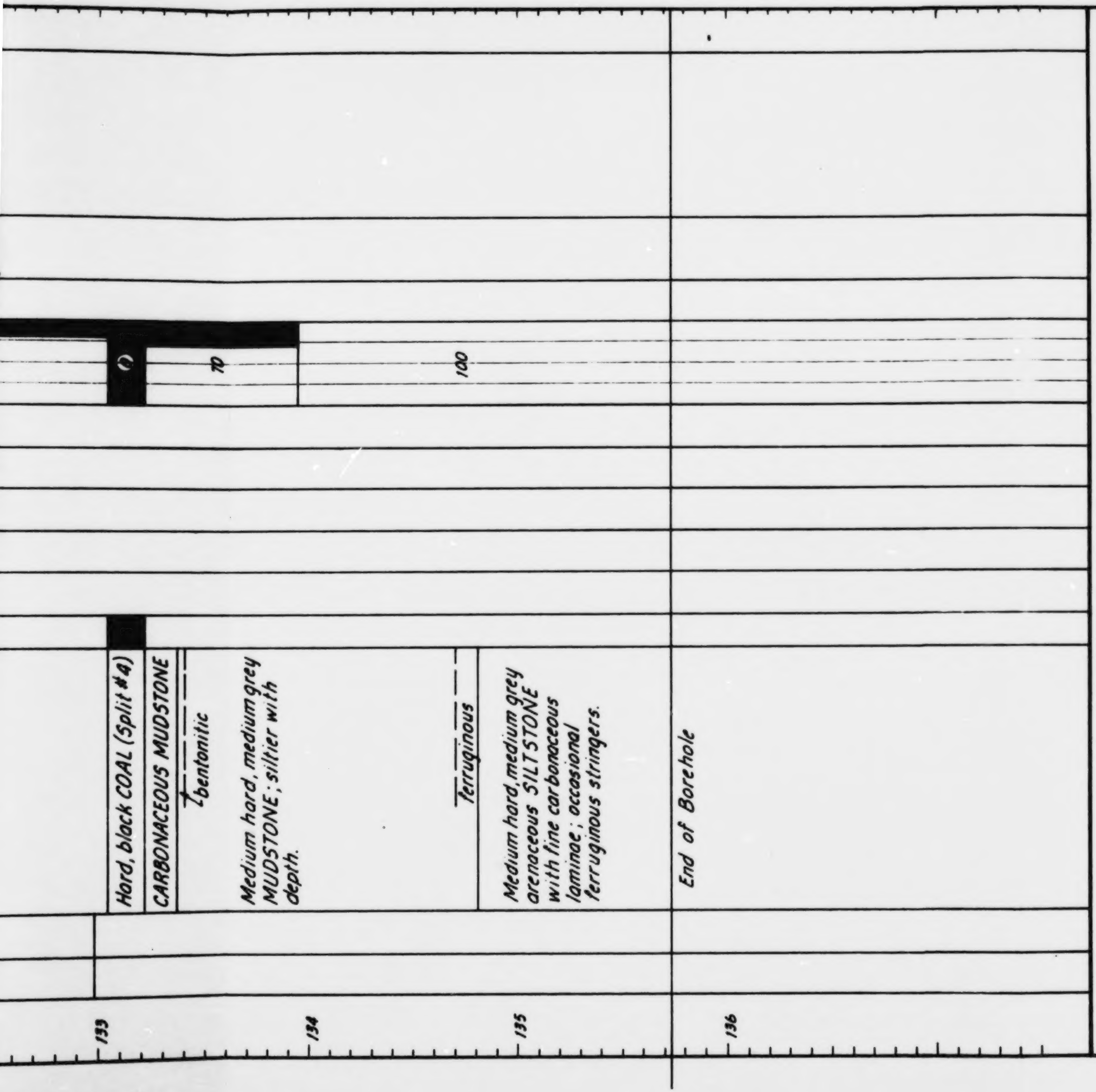
Macro
Plan
Curv
Step
Irreg

NOTE

1) See also ge
in FIGURE

ABBREVIATIO

| | |
|---|---|
| B.D. | Bulk De |
| U.C. | Uniaxial |
| F.S. | Free Sw |
| S.D. | Slake D |
| P.I. | Plastici |


0
70
100
Hard, black COAL (Split #4)
CARBONACEOUS MUDSTONE
bentonitic
Medium hard, medium grey MUDSTONE; siltier with depth.
Ferruginous
Medium hard, medium grey arenaceous SILTSTONE with fine carbonaceous laminae; occasional ferruginous stringers.
End of Borehole
133
134
135
136

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## DRILLING AND SURVEY DATA

Drill Rig - Rotary, Ingersoll Rand T.H. 60, Air Flush.
Bit - Tungsten Carbide, 76mm x 140mm.
Contractor - Alberta Southern Exploration Drilling Ltd.
Date Drilled - Mar. 2 , 1983 by B. Bierman.
Date Logged - Mar. 2 , 1983 by W. Claeys.
Collar Elevation: 930.53m , Location: 5 524 898.0mN
Drillhole Orientation - Vertical. 79 785.0mE
Core Barrel - 305mm Christensen.
Casing - 152 mm, hammered to 55.3m and abandoned.

## LEGEND

☒ Core loss - assumed to have occured at top of run.
mm3 Gouge with thickness in millimeters, t = trace.
xxx Broken or Brecciated.
HHH Broken - mainly horizontally.
CIB Concretionary Ironstone Band.

## FRACTURE ROUGHNESS

| Macro | Micro |
|---|---|
| — Planar | K Slick |
| ◡ Curve | S Smooth |
| ~ Stepped | R Rough |
| ∿ Irregular | |

## NOTE

1) See also geophysical logs by Roke and core photographs in FIGURE 5-14

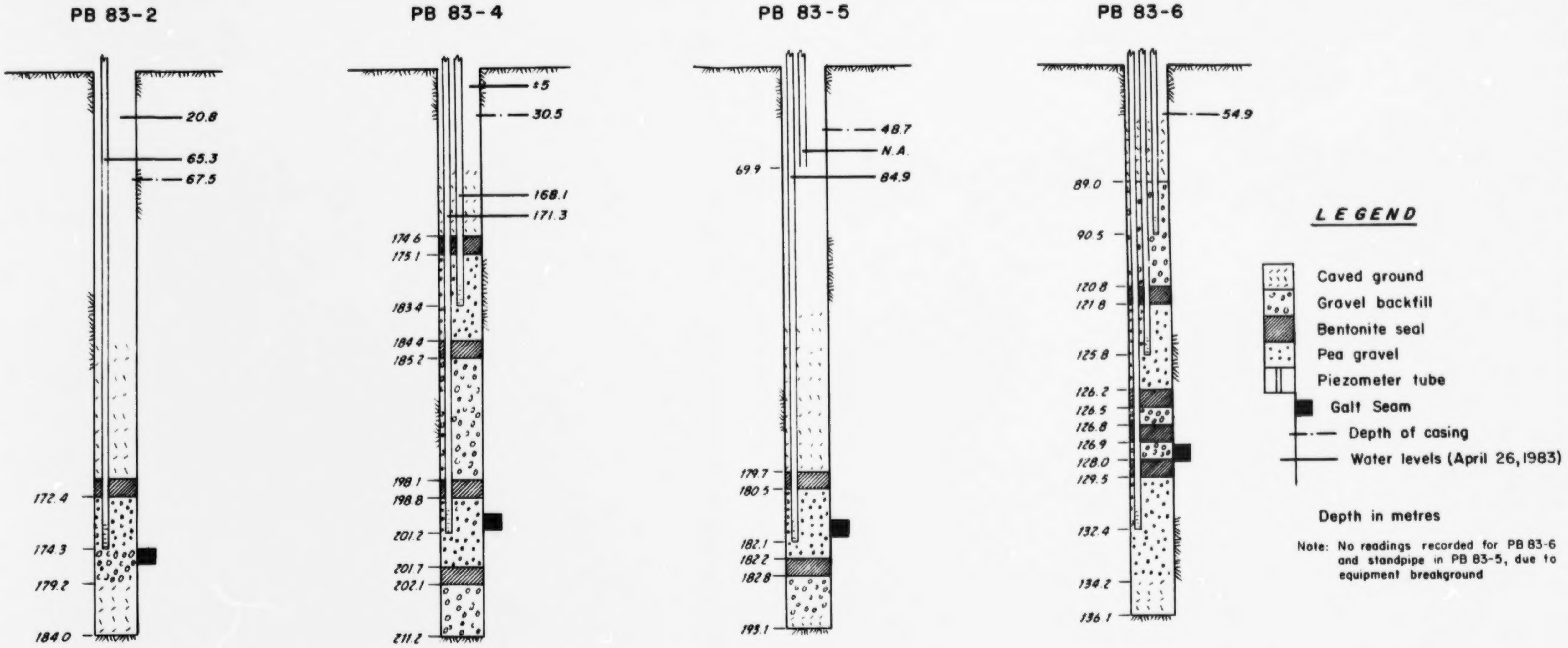
## ABBREVIATIONS

| | |
|---|---|
| B.D. | Bulk Density |
| U.C. | Uniaxial Compressive Strength |
| F.S. | Free Swell |
| S.D. | Slake Durability |
| P.I. | Plasticity Index |

FIGURE 5-7

PRECAMBRIAN SHIELD RESOURCES LIMITED
COAL DIVISION
PICTURE BUTTE COAL PROJECT
A TECHNICAL ASSESSMENT OF PICTURE BUTTE
1983
**GEOTECHNICAL CORE LOG**
**DRILLHOLE PB 83-6**

PA88-066


PB 83-2
20.8
65.3
67.5
172.4
174.3
179.2
184.0
PB 83-4
±5
30.5
168.1
171.3
174.6
175.1
183.4
184.4
185.2
198.1
198.8
201.2
201.7
202.1
211.2
PB 83-5
48.7
N.A.
69.9
84.9
179.7
180.5
182.1
182.2
182.8
193.1
PB 83-6
54.9
89.0
90.5
120.8
121.8
125.8
126.2
126.5
126.8
126.9
128.0
129.5
132.4
134.2
136.1
LEGEND
Caved ground
Gravel backfill
Bentonite seal
Pea gravel
Piezometer tube
Galt Seam
Depth of casing
Water levels (April 26,1983)

Depth in metres

Note: No readings recorded for PB 83-6 and standpipe in PB 83-5, due to equipment breakground

NOT TO SCALE

FIGURE 5-8

PRECAMBRIAN SHIELD RESOURCES LIMITED
COAL DIVISION
PICTURE BUTTE COAL PROJECT
A TECHNICAL ASSESSMENT OF PICTURE BUTTE
1983

SCHEMATIC DETAILS OF
PIEZOMETER INSTALLATIONS

PA98-067

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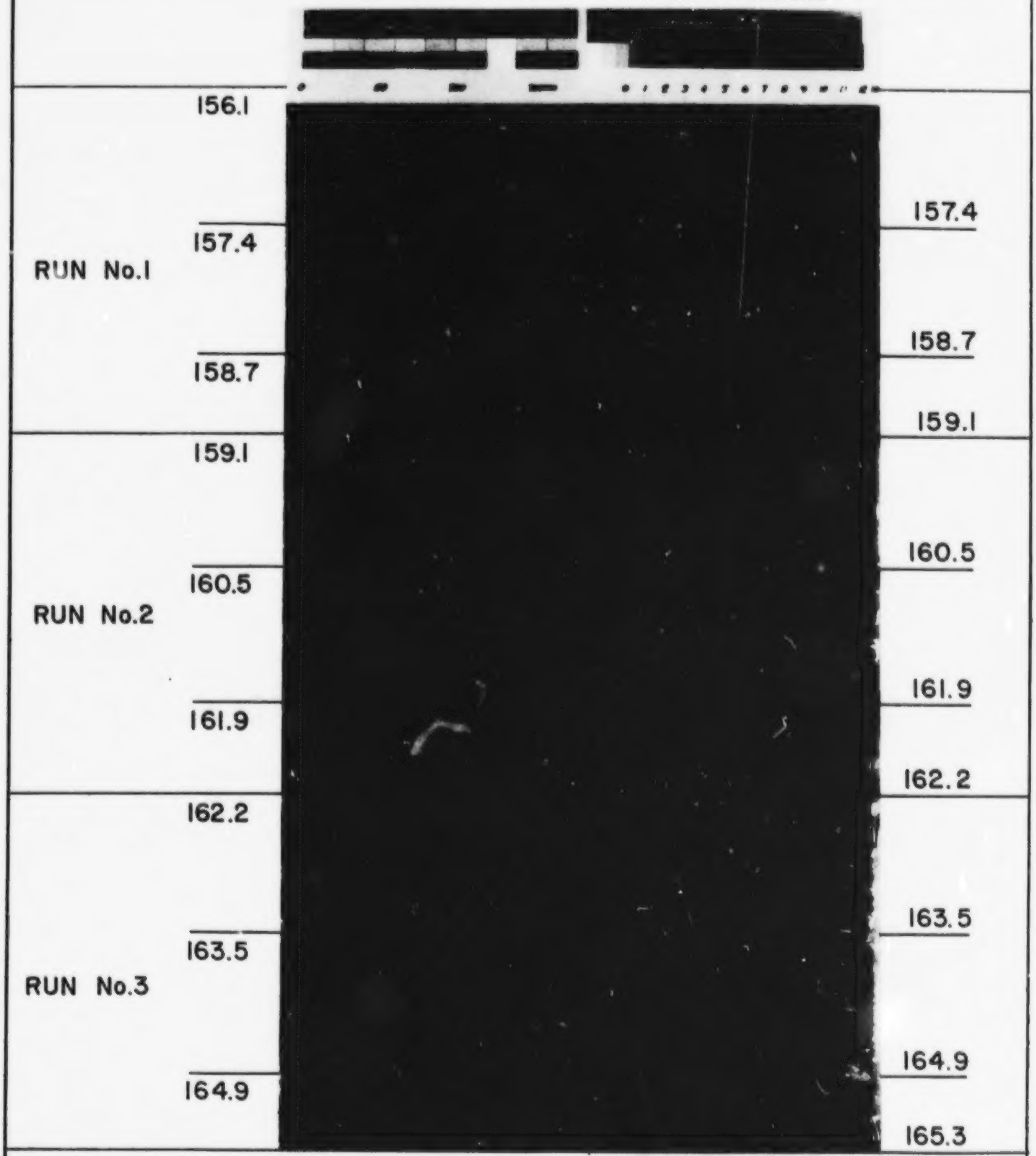

RUN No.1
RUN No.2
RUN No.3
156.1
157.4
157.4
158.7
158.7
159.1
159.1
160.5
160.5
161.9
161.9
162.2
162.2
163.5
163.5
164.9
164.9
165.3

FIGURE 5-9

PRECAMBRIAN SHIELD RESOURCES LIMITED
COAL DIVISION
PICTURE BUTTE COAL PROJECT
A TECHNICAL ASSESSMENT OF PICTURE BUTTE
1983

ROCK CORE – DRILLHOLE PB 83-1

Sheet 1 of 2

PA98-068A

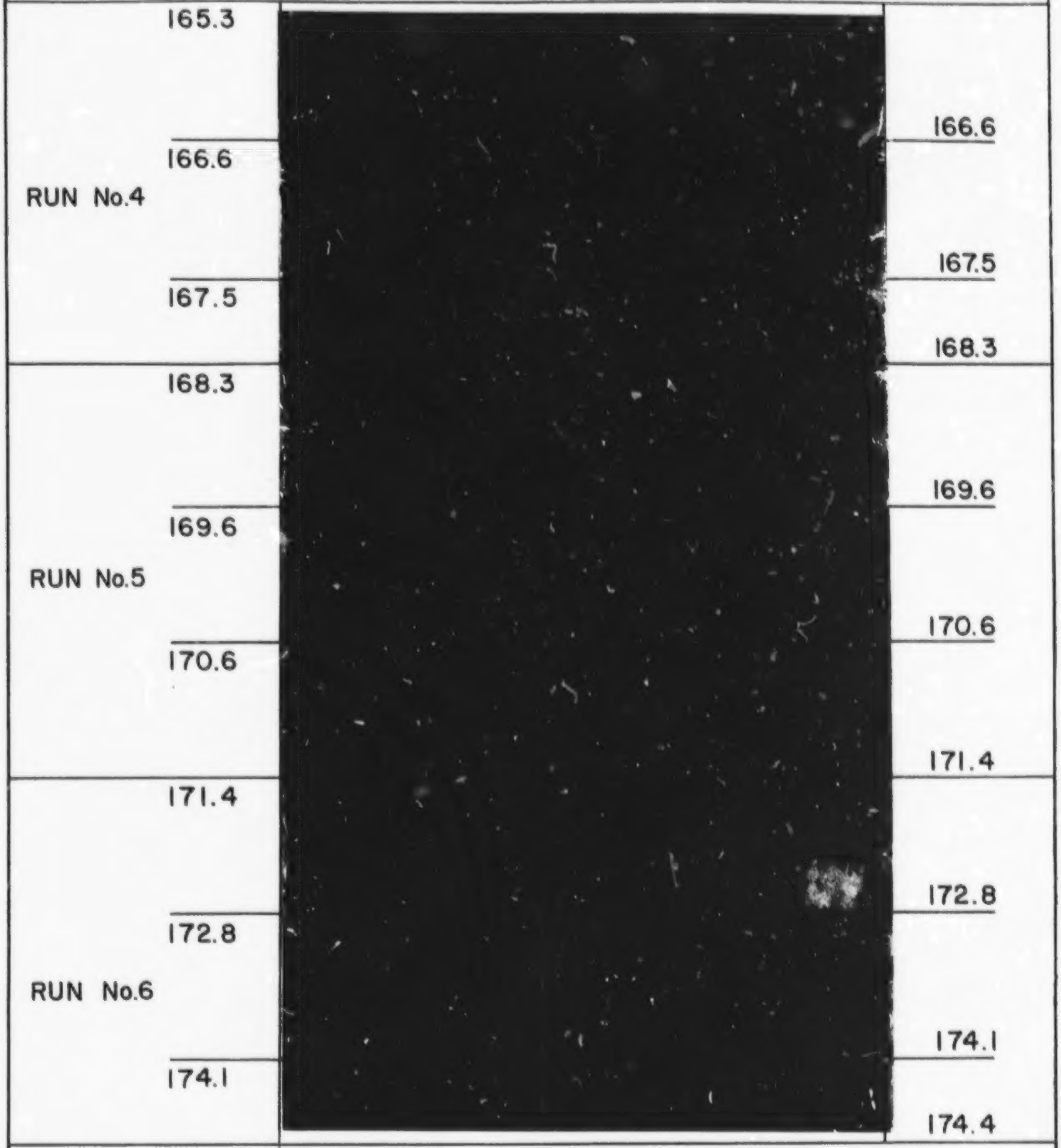

165.3
166.6
RUN No.4
167.5
168.3
169.6
RUN No.5
170.6
171.4
172.8
RUN No.6
174.1
166.6
167.5
168.3
169.6
170.6
171.4
172.8
174.1
174.4

FIGURE 5 - 9
PRECAMBRIAN SHIELD RESOURCES LIMITED
COAL DIVISION
PICTURE BUTTE COAL PROJECT
A TECHNICAL ASSESSMENT OF PICTURE BUTTE
1983
ROCK CORE - DRILLHOLE PB 83-1
Sheet 2 of 2

**Associated Mining Consultants Ltd.**
**Golder Associates**

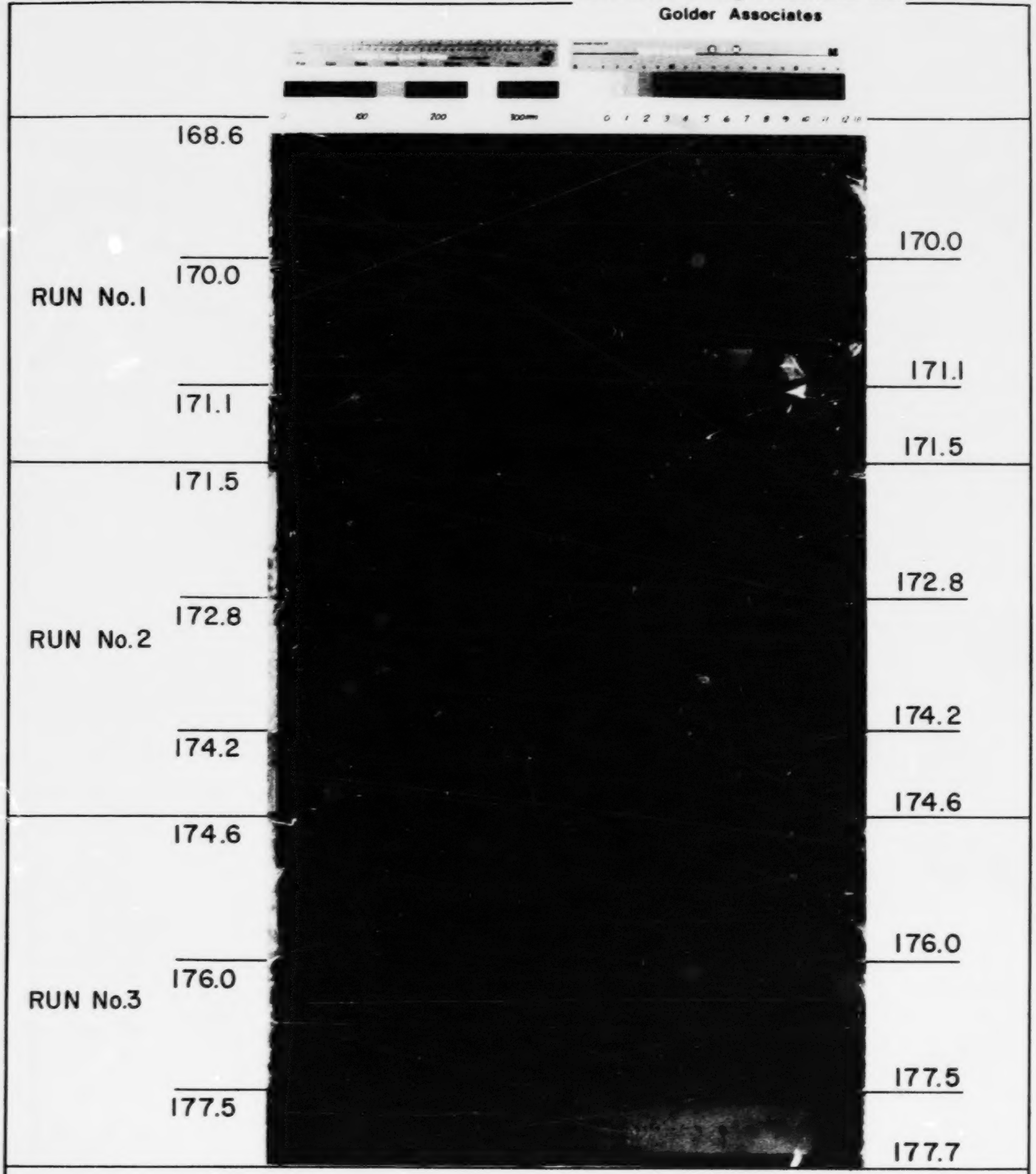

0
100
200
300mm
0 1 2 3 4 5 6 7 8 9 10 11 12
168.6
RUN No.1
170.0
171.1
171.5
RUN No.2
172.8
174.2
174.6
RUN No.3
176.0
177.5
170.0
171.1
171.5
172.8
174.2
174.6
176.0
177.5
177.7

FIGURE 5-10

**PRECAMBRIAN SHIELD RESOURCES LIMITED**
**COAL DIVISION**
**PICTURE BUTTE COAL PROJECT**
**A TECHNICAL ASSESSMENT OF PICTURE BUTTE**
**1983**

ROCK CORE - DRILLHOLE PB 83-2

Sheet 1 of 2

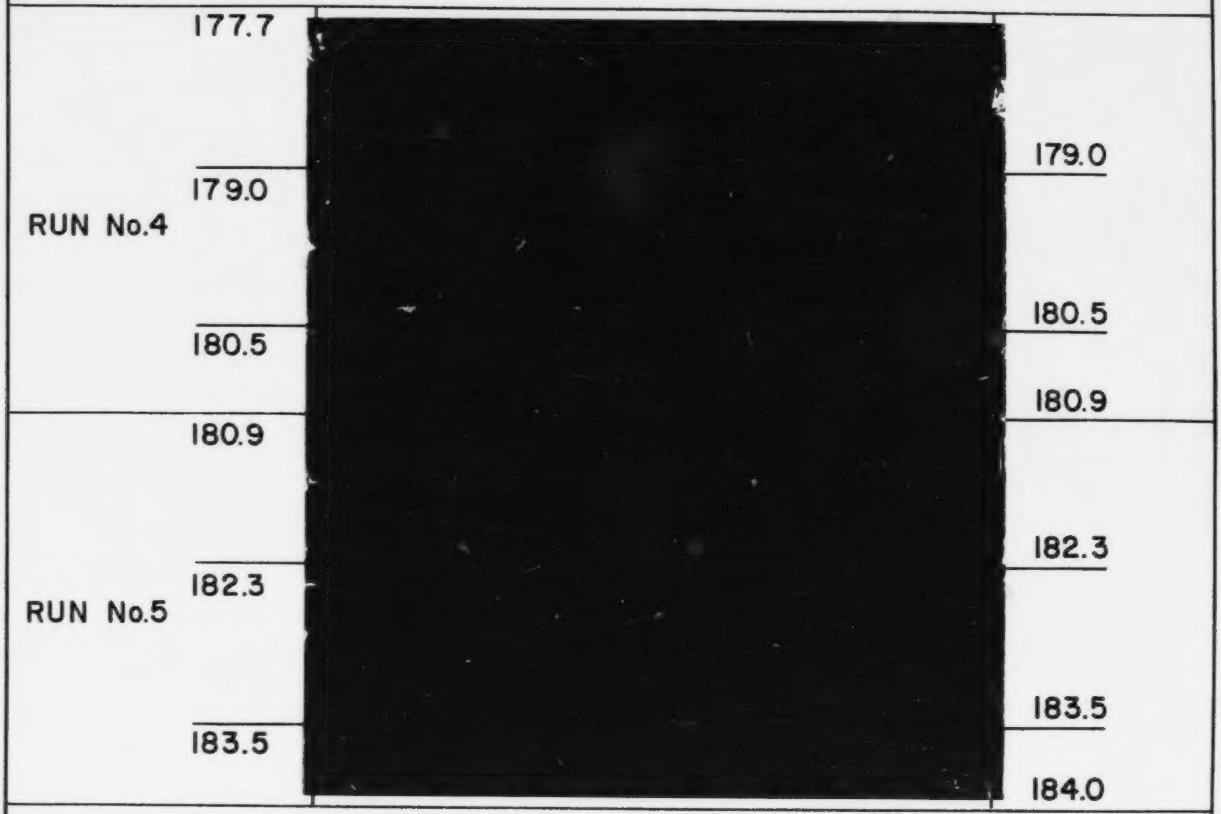
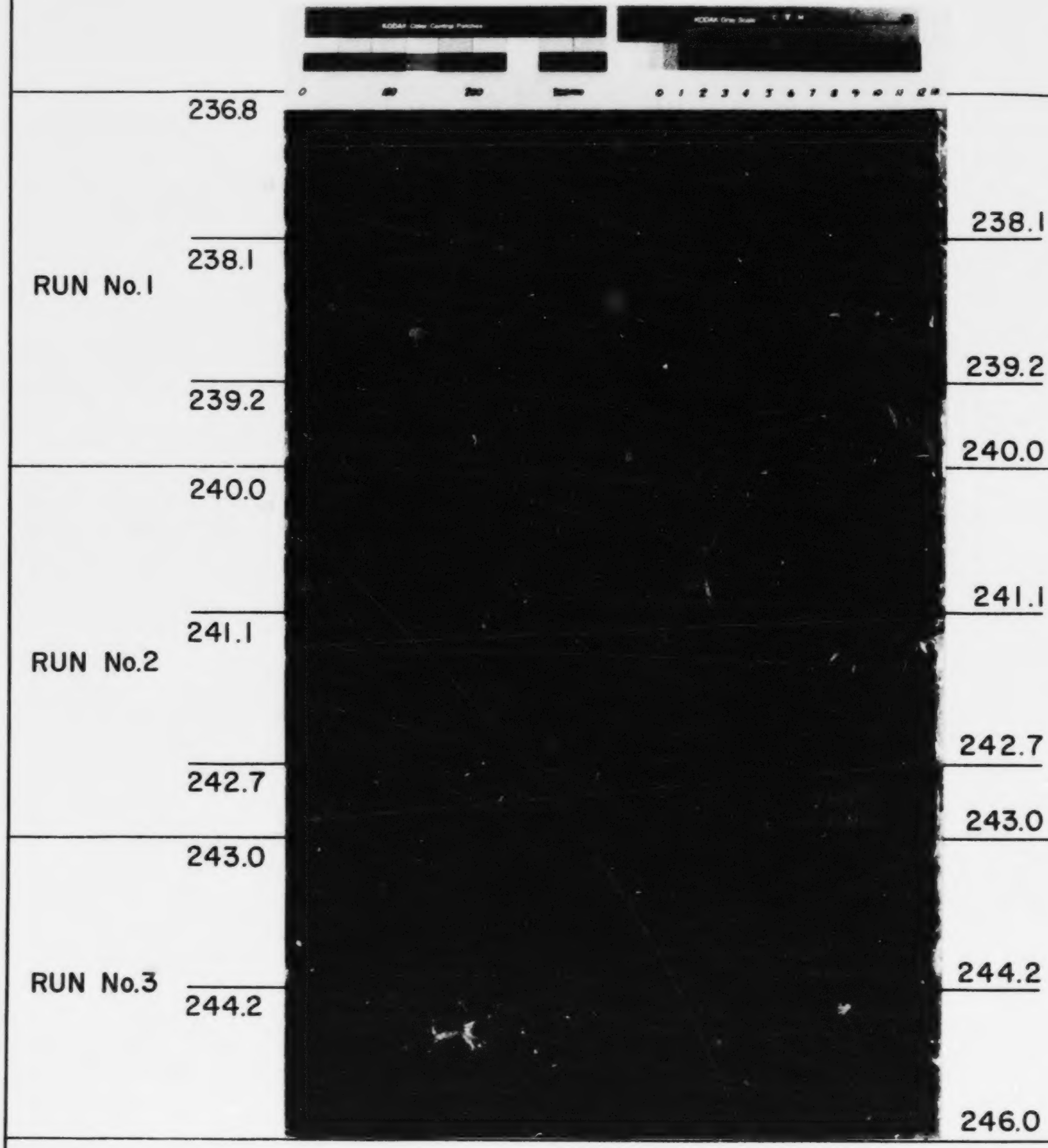

177.7
179.0
RUN No.4
180.5
180.9
182.3
RUN No.5
183.5
179.0
180.5
180.9
182.3
183.5
184.0

FIGURE 5-10
PRECAMBRIAN SHIELD RESOURCES LIMITED
COAL DIVISION
PICTURE BUTTE COAL PROJECT
A TECHNICAL ASSESSMENT OF PICTURE BUTTE
1983
ROCK CORE - DRILLHOLE PB 83-2
Sheet 2 of 2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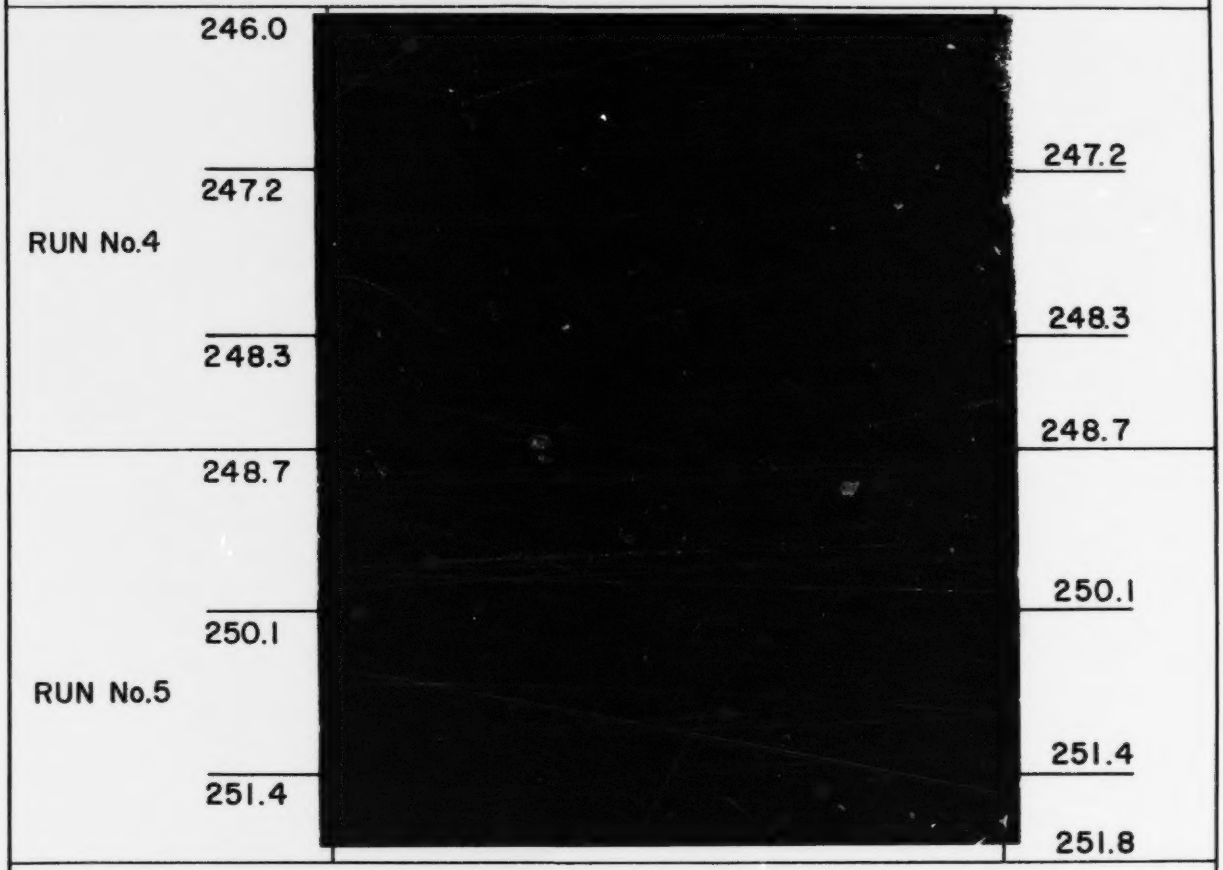
238.1
238.1
RUN No.1
239.2
239.2
240.0
240.0
241.1
241.1
RUN No.2
242.7
242.7
243.0
243.0
RUN No.3
244.2
244.2
246.0

FIGURE 5-11
PRECAMBRIAN SHIELD RESOURCES LIMITED
COAL DIVISION
PICTURE BUTTE COAL PROJECT
A TECHNICAL ASSESSMENT OF PICTURE BUTTE
1983
ROCK CORE – DRILLHOLE PB 83-3
Sheet 1 of 2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247.2
RUN No.4
248.3
248.3
248.7
248.7
250.1
250.1
RUN No.5
251.4
251.4
251.8

FIGURE 5 - 11
PRECAMBRIAN SHIELD RESOURCES LIMITED
COAL DIVISION
PICTURE BUTTE COAL PROJECT
A TECHNICAL ASSESSMENT OF PICTURE BUTTE
1983
ROCK CORE - DRILLHOLE PB 83-3
Sheet 2 of 2

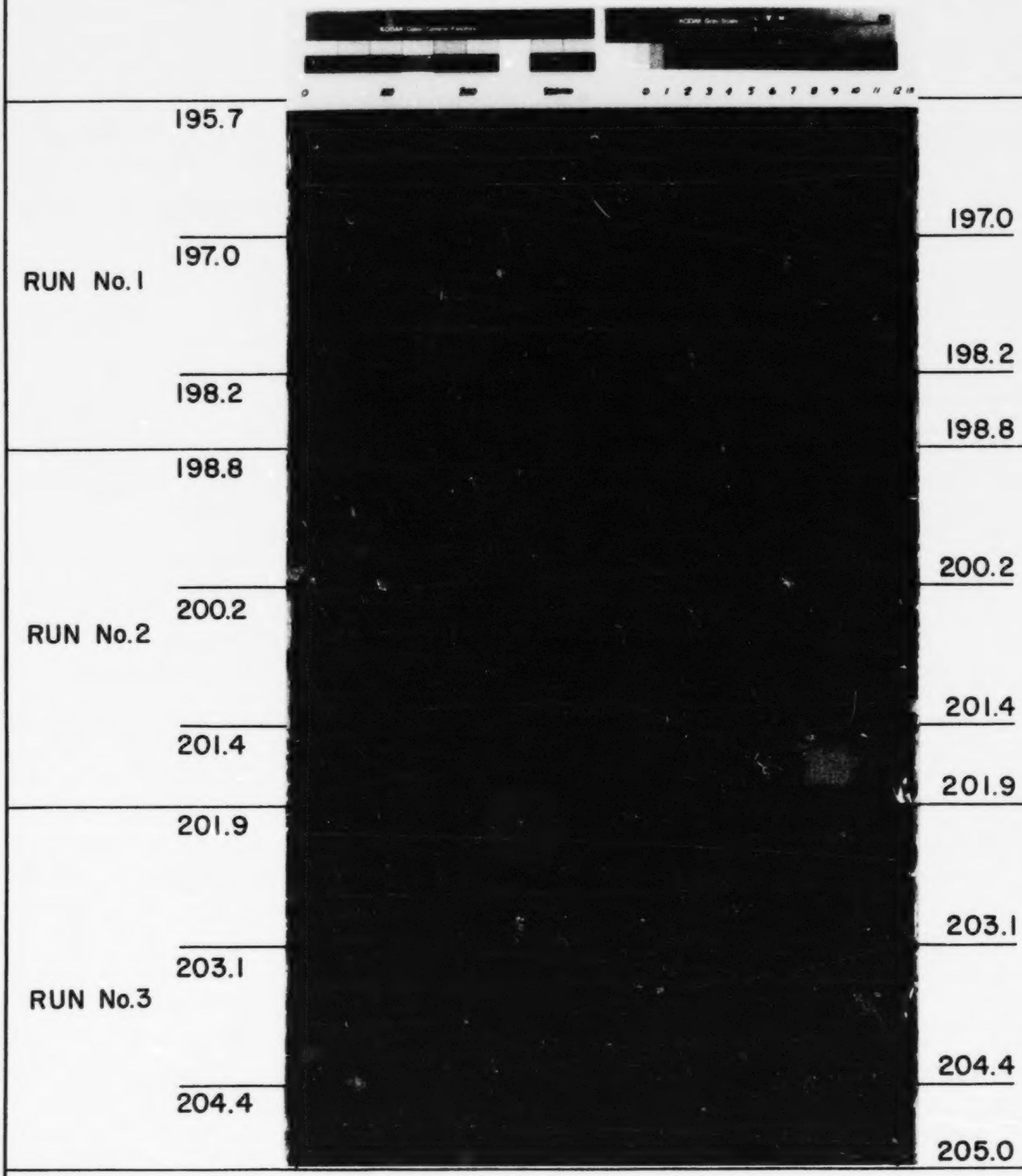
195.7
197.0
197.0
RUN No.1
198.2
198.2
198.8
198.8
200.2
200.2
RUN No.2
201.4
201.4
201.9
201.9
203.1
203.1
RUN No.3
204.4
204.4
205.0
0 1 2 3 4 5 6 7 8 9 10 11 12

FIGURE 5-12
**PRECAMBRIAN SHIELD RESOURCES LIMITED**
**COAL DIVISION**
**PICTURE BUTTE COAL PROJECT**
**A TECHNICAL ASSESSMENT OF PICTURE BUTTE**
**1983**
ROCK CORE - DRILLHOLE PB 83-4
Sheet 1 of 2

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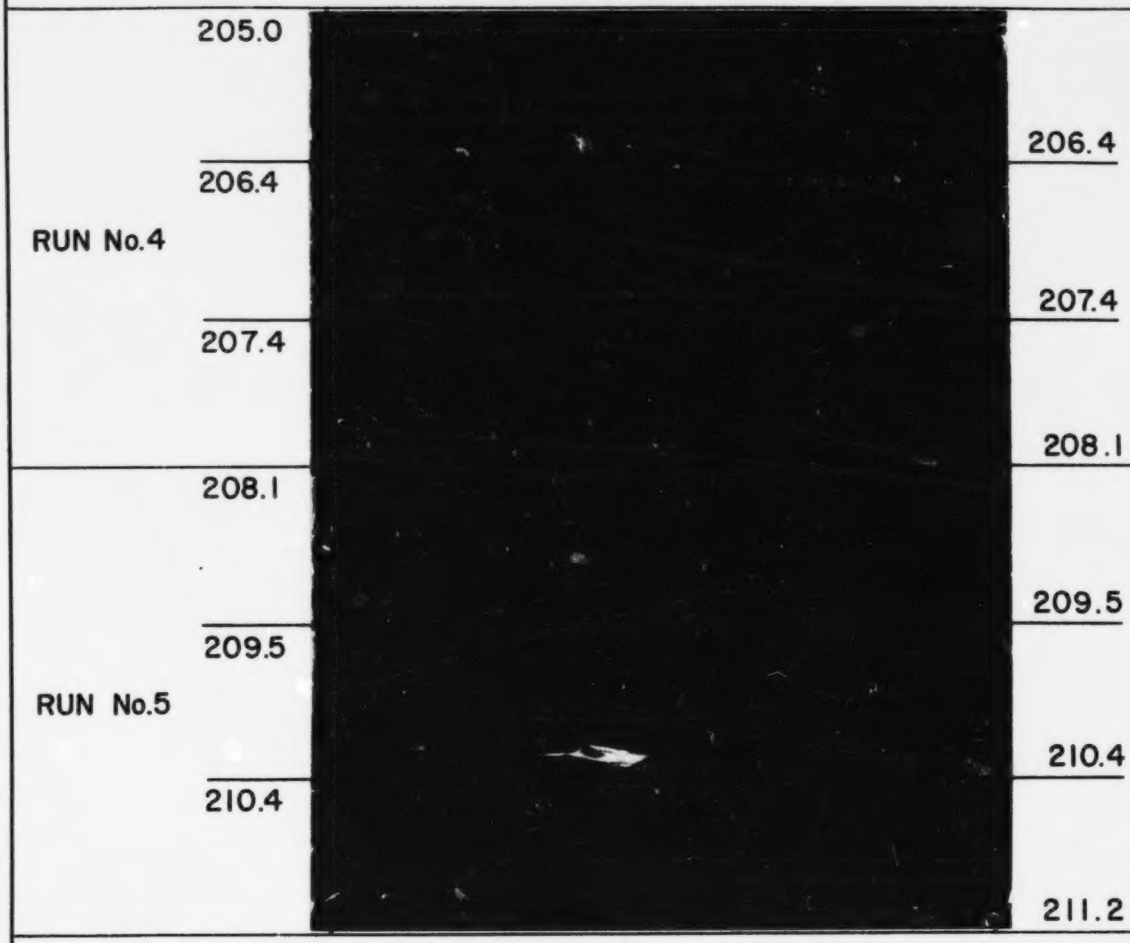
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206.4
206.4
RUN No.4
207.4
207.4
208.1
208.1
209.5
209.5
RUN No.5
210.4
210.4
211.2

FIGURE 5-12
PRECAMBRIAN SHIELD RESOURCES LIMITED
COAL DIVISION
PICTURE BUTTE COAL PROJECT
A TECHNICAL ASSESSMENT OF PICTURE BUTTE
1983
ROCK CORE - DRILLHOLE PB 83-4
Sheet 2 of 2

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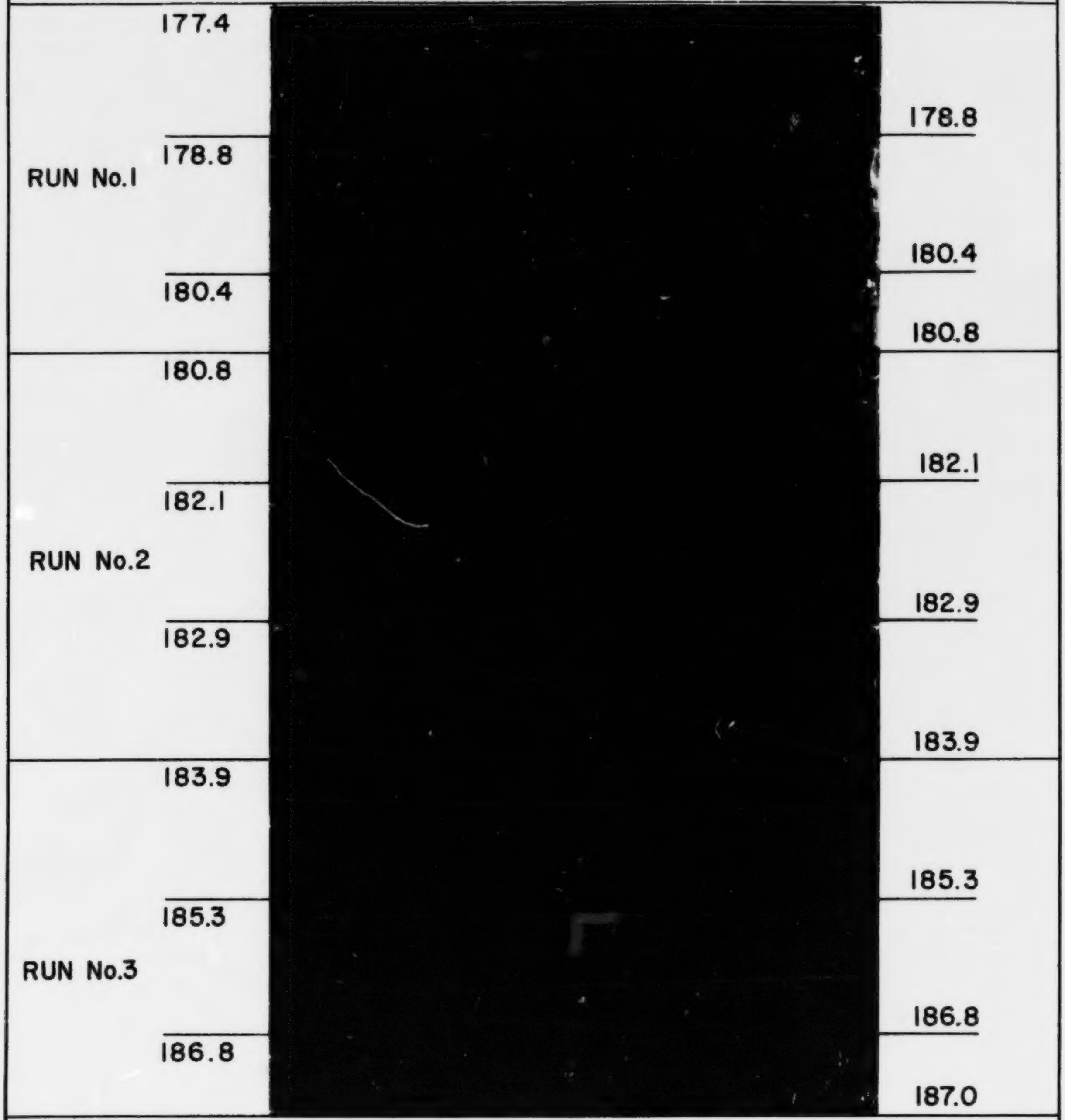

177.4
178.8
RUN No.1
178.8
180.4
180.4
180.8
180.8
182.1
182.1
RUN No.2
182.9
182.9
183.9
183.9
185.3
185.3
RUN No.3
186.8
186.8
187.0

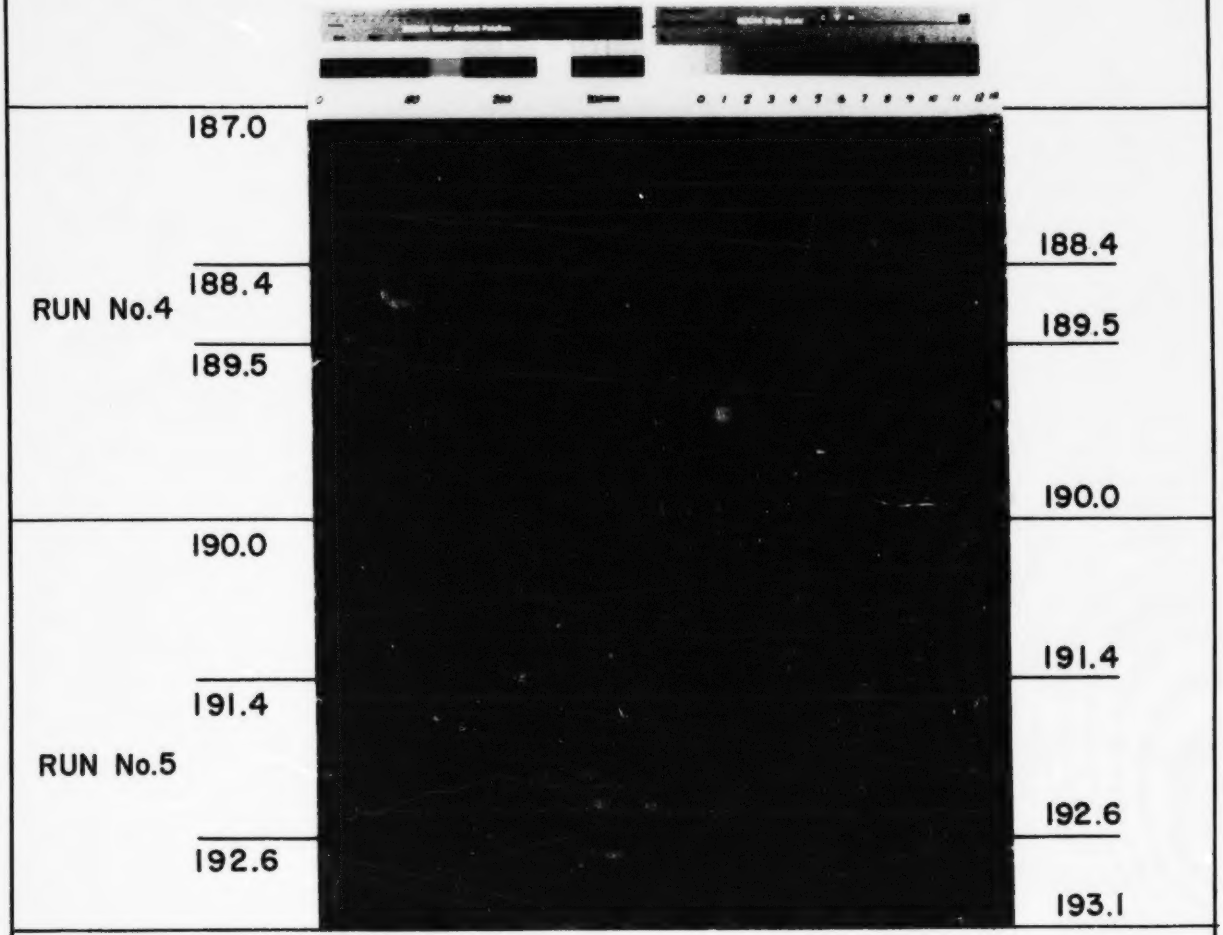
FIGURE 5-13

**PRECAMBRIAN SHIELD RESOURCES LIMITED**
**COAL DIVISION**
**PICTURE BUTTE COAL PROJECT**
**A TECHNICAL ASSESSMENT OF PICTURE BUTTE**
**1983**

ROCK CORE - DRILLHOLE PB 83-5

Sheet 1 of 2

PA98-072A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188.4
RUN No.4
189.5
190.0
191.4
RUN No.5
192.6
188.4
189.5
190.0
191.4
192.6
193.1

FIGURE 5-13
PRECAMBRIAN SHIELD RESOURCES LIMITED
COAL DIVISION
PICTURE BUTTE COAL PROJECT
A TECHNICAL ASSESSMENT OF PICTURE BUTTE
1983

ROCK CORE – DRILLHOLE PB 83-5

Sheet 2 of 2

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**Golder Associates**

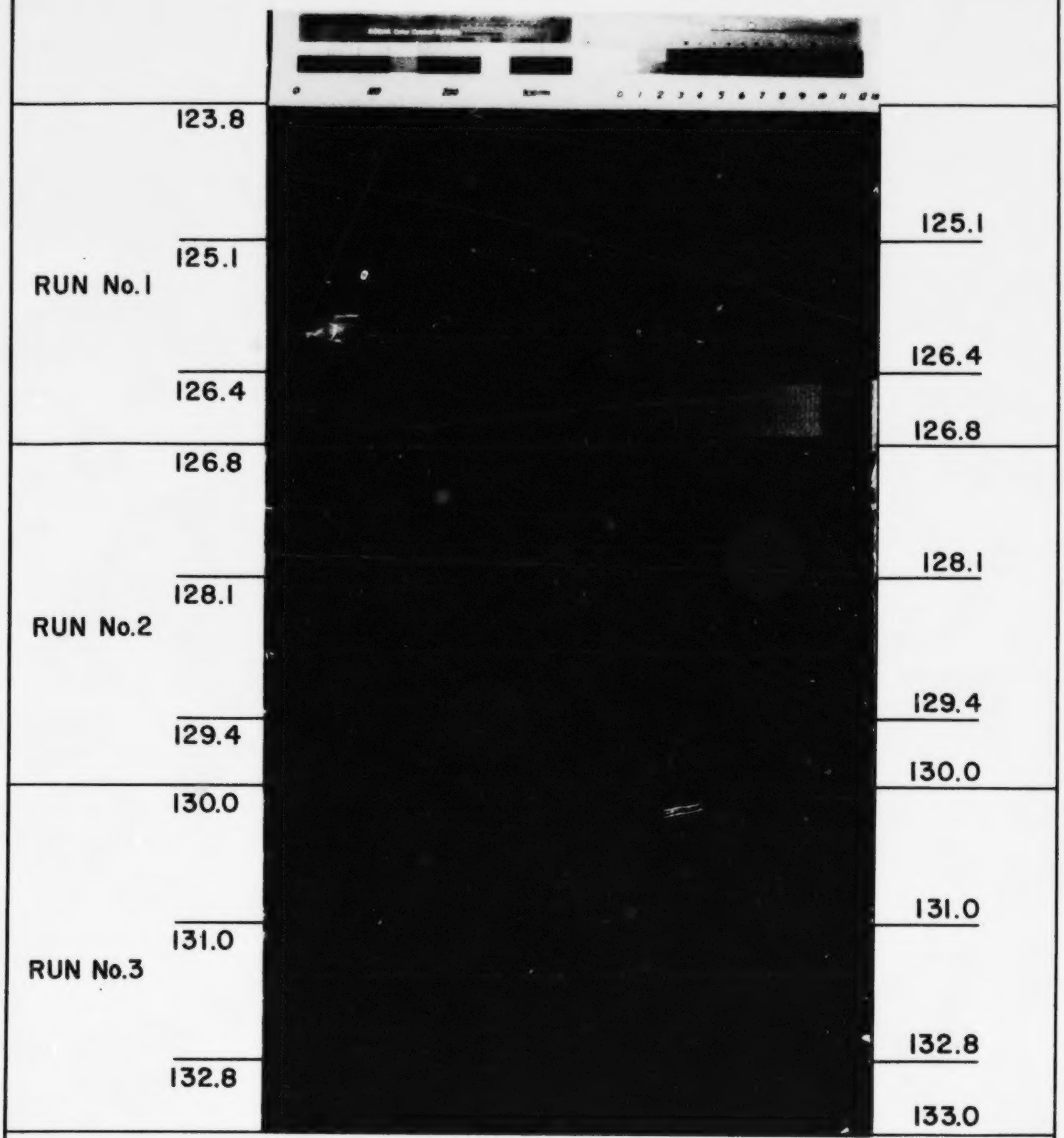
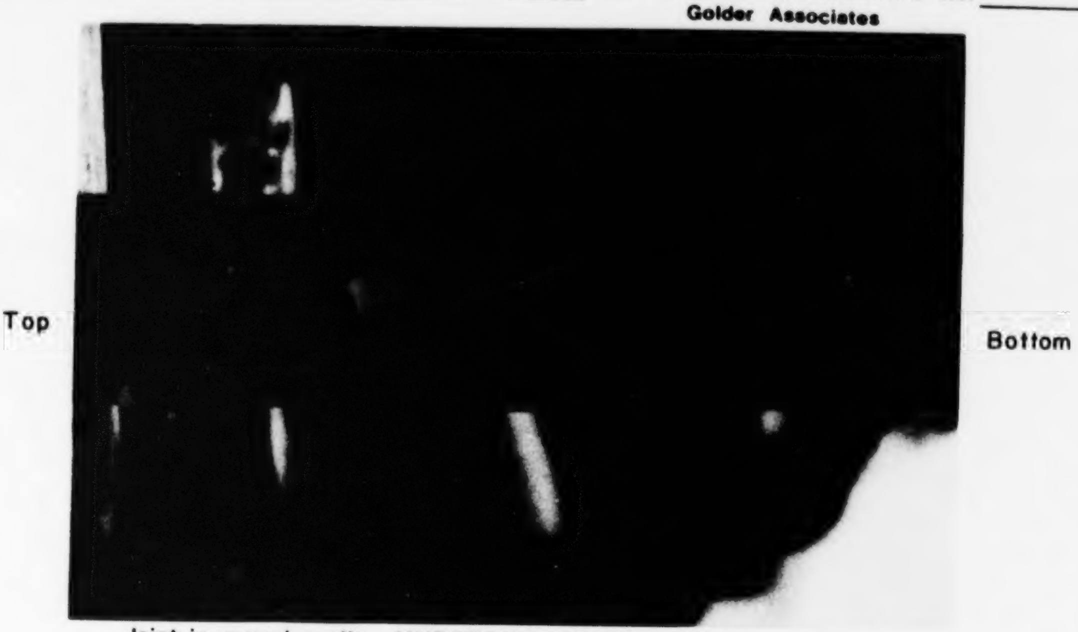

123.8
125.1
RUN No.1
126.4
126.8
128.1
RUN No.2
129.4
130.0
131.0
RUN No.3
132.8
125.1
126.4
126.8
128.1
129.4
130.0
131.0
132.8
133.0

FIGURE 5-14
PRECAMBRIAN SHIELD RESOURCES LIMITED
COAL DIVISION
PICTURE BUTTE COAL PROJECT
A TECHNICAL ASSESSMENT OF PICTURE BUTTE
1983
ROCK CORE - DRILLHOLE PB 83-6
Sheet 1 of 2

133.0
134.1
RUN No.4
135.5
134.1
135.5
135.7

FIGURE 5-14
PRECAMBRIAN SHIELD RESOURCES LIMITED
COAL DIVISION
PICTURE BUTTE COAL PROJECT
A TECHNICAL ASSESSMENT OF PICTURE BUTTE
1983
ROCK CORE - DRILLHOLE PB 83-6
Sheet 2 of 2



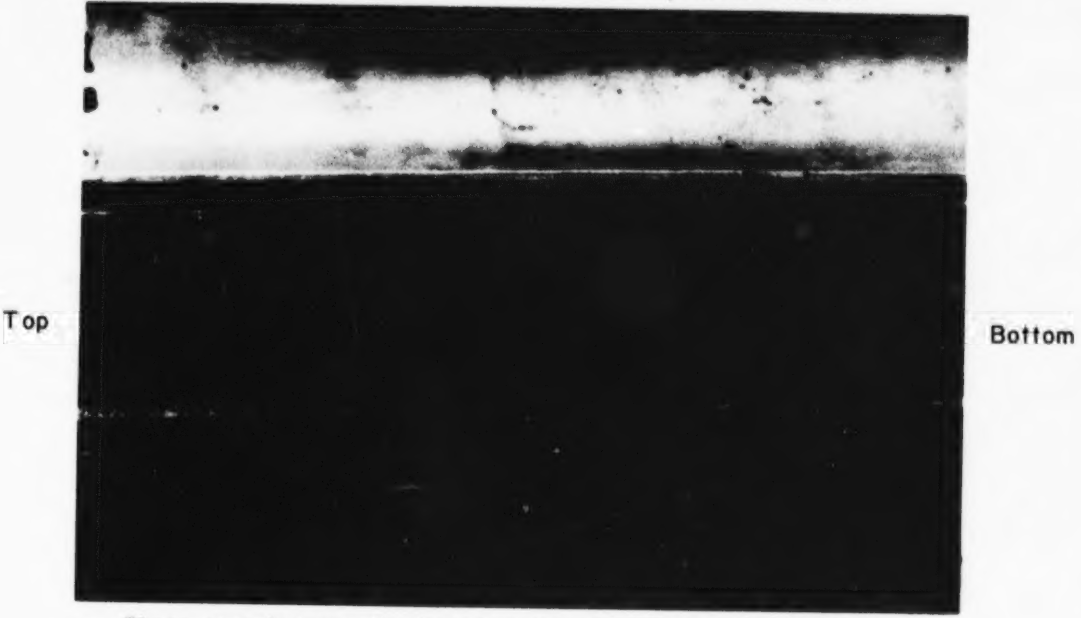
Joint in massive silty MUDSTONE; PB 83-4, 210.8 - 210.9 m

Laminated to wavy bedded silty MUDSTONE overlying thin Ironstone band; PB 83-5, 185.2 - 185.4 m

FIGURE 5-15
PRECAMBRIAN SHIELD RESOURCES LIMITED
COAL DIVISION
PICTURE BUTTE COAL PROJECT
A TECHNICAL ASSESSMENT OF PICTURE BUTTE
1983

LITHOLOGICAL AND STRUCTURAL
FEATURES IN ROCK CORE

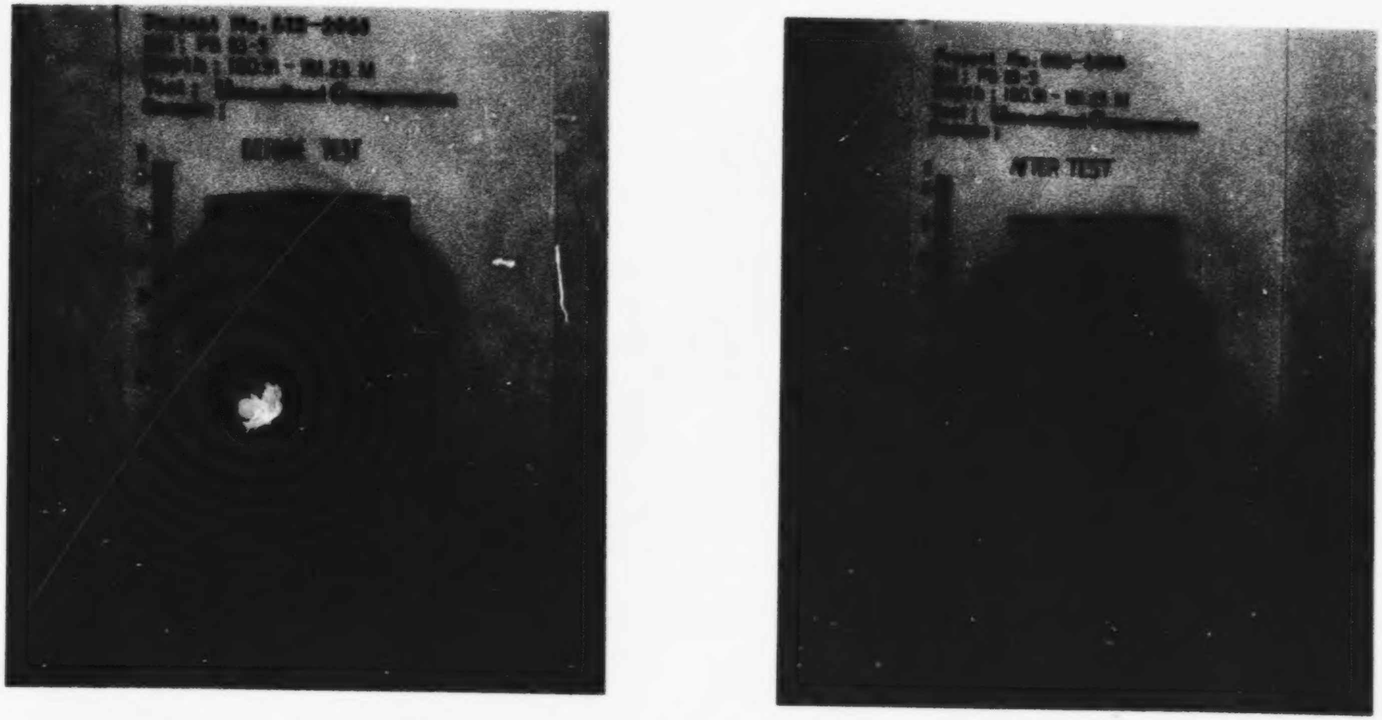
Cleat in COAL (10° to core axis); PB 83-6, 127.9 - 128.1 m



Shear zone between laminated, calcareous MUDSTONE (top) and softer MUDSTONE (bottom); PB 83-6, 131.3 - 131.4 m

FIGURE 5 - 16
**PRECAMBRIAN SHIELD RESOURCES LIMITED**
**COAL DIVISION**
**PICTURE BUTTE COAL PROJECT**
**A TECHNICAL ASSESSMENT OF PICTURE BUTTE**
**1983**

STRUCTURAL FEATURES
IN ROCK CORE

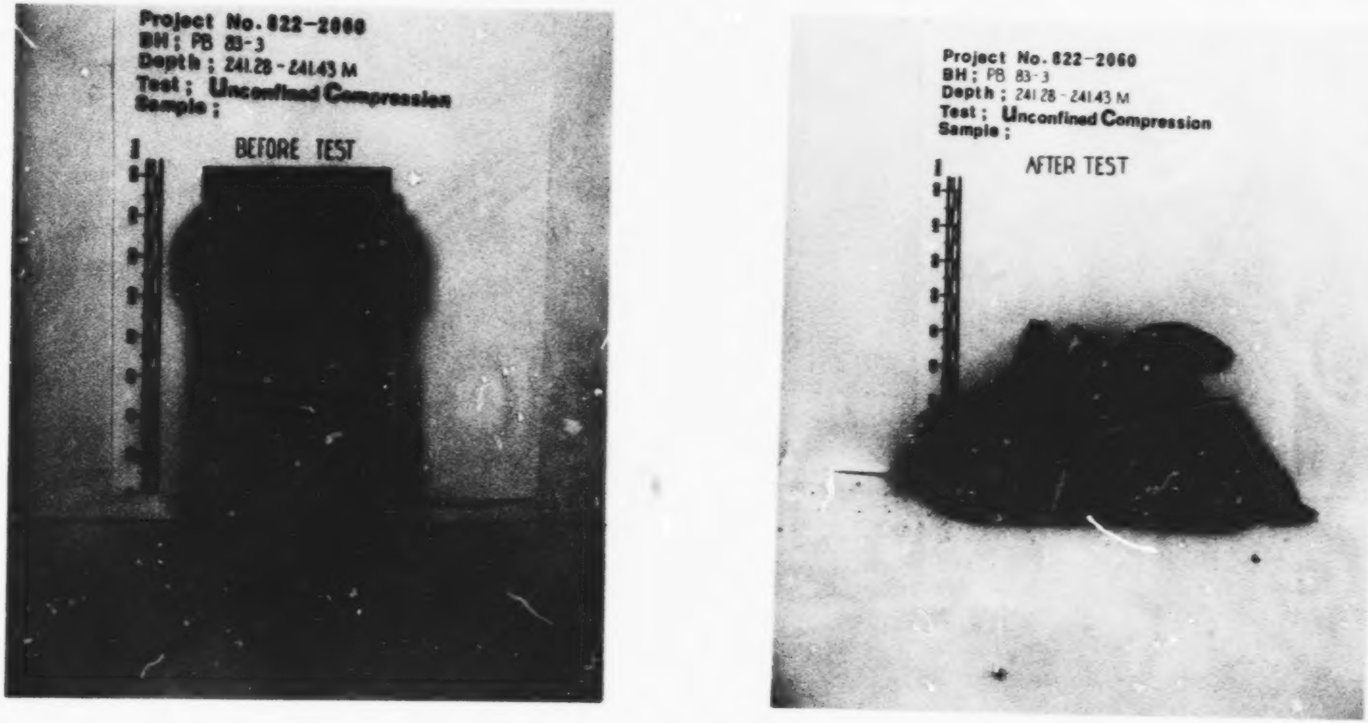


Drillhole PB 83-5

Location 180.9 - 181.2 m
0.2 m above GALT SEAM

FIGURE 5 - 17
PRECAMBRIAN SHIELD RESOURCES LIMITED
COAL DIVISION
PICTURE BUTTE COAL PROJECT
A TECHNICAL ASSESSMENT OF PICTURE BUTTE
1983
UNCONFINED COMPRESSION TEST - MUDSTONE

FIGURE 5 - 17
PB 83-5

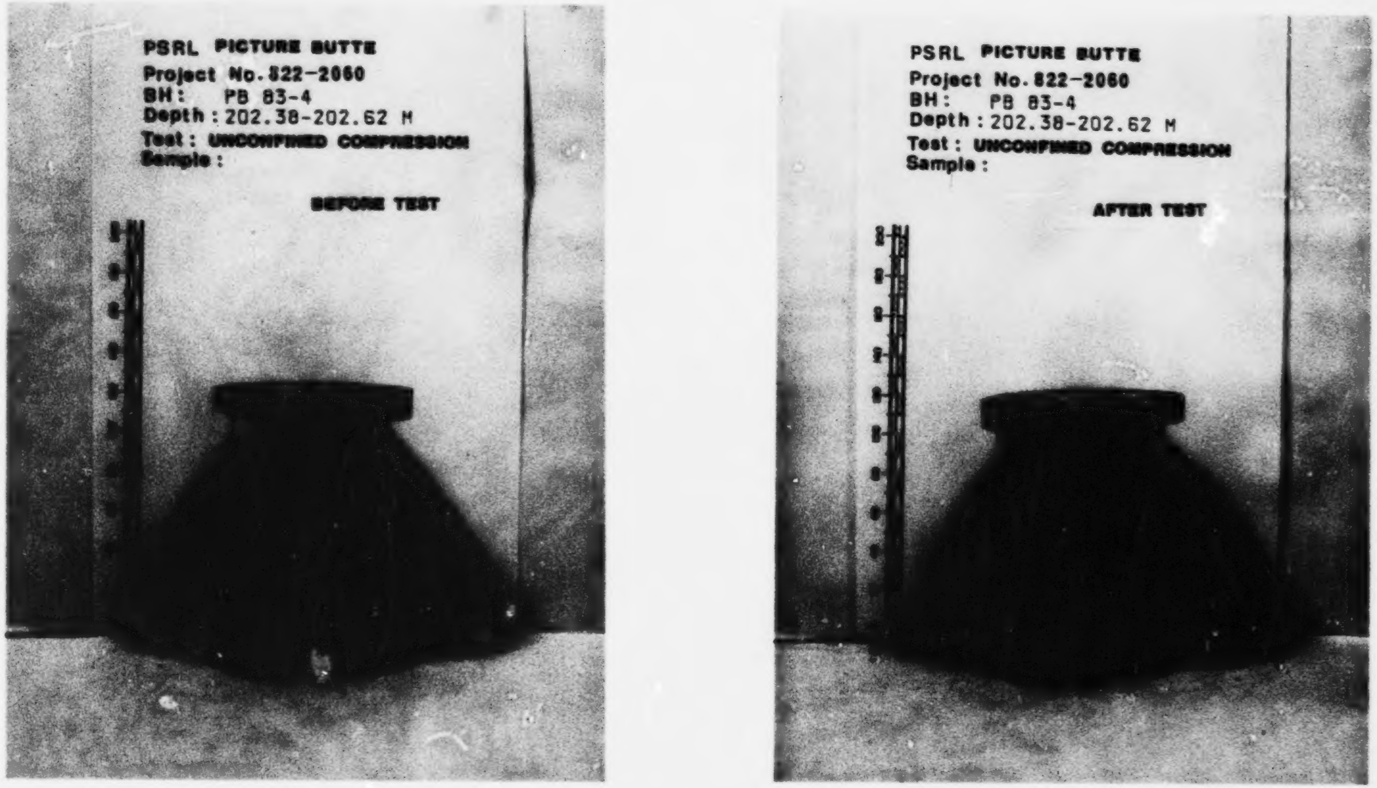

Project No. 822-2060
BH ; PB 83-3
Depth ; 241.28 - 241.43 M
Test ; Unconfined Compression
Sample ;
BEFORE TEST
Project No. 822-2060
BH ; PB 83-3
Depth ; 241.28 - 241.43 M
Test ; Unconfined Compression
Sample ;
AFTER TEST

Drillhole PB 83-3

Location 241.3 - 241.4 m

FIGURE 5-18
PB 83-3

FIGURE 5-18
PRECAMBRIAN SHIELD RESOURCES LIMITED
COAL DIVISION
PICTURE BUTTE COAL PROJECT
A TECHNICAL ASSESSMENT OF PICTURE BUTTE
1983
UNCONFINED COMPRESSION TEST - GALT COAL SEAM

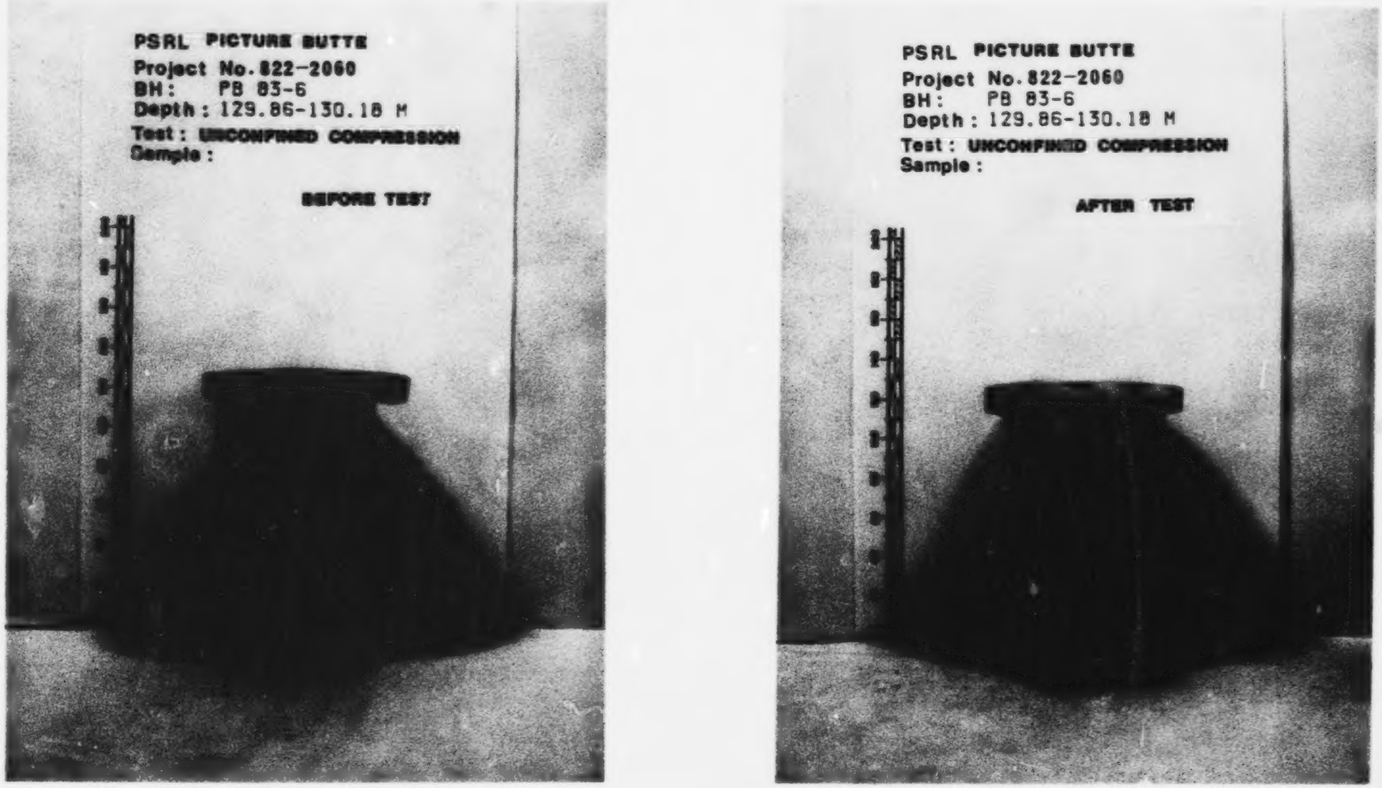

PSRL PICTURE BUTTE
Project No. 822-2060
BH: PB 83-4
Depth : 202.38-202.62 M
Test : UNCONFINED COMPRESSION
Sample :
BEFORE TEST
PSRL PICTURE BUTTE
Project No. 822-2060
BH: PB 83-4
Depth : 202.38-202.62 M
Test : UNCONFINED COMPRESSION
Sample :
AFTER TEST

Drillhole PB 83-4

Location 202.4 - 202.6 m
1.1m below GALT SEAM

FIGURE 5 - 19
PRECAMBRIAN SHIELD RESOURCES LIMITED
COAL DIVISION
PICTURE BUTTE COAL PROJECT
A TECHNICAL ASSESSMENT OF PICTURE BUTTE
1983
UNCONFINED COMPRESSION TEST - MUDSTONE

FIGURE 5 - 19
PB 83 - 4


PSRL PICTURE BUTTE
Project No. 822-2060
BH: PB 83-6
Depth : 129.86-130.18 M
Test : UNCONFINED COMPRESSION
Sample :
BEFORE TEST
PSRL PICTURE BUTTE
Project No. 822-2060
BH: PB 83-6
Depth : 129.86-130.18 M
Test : UNCONFINED COMPRESSION
Sample :
AFTER TEST

Drillhole PB 83-6

Location 129.9 - 130.2 m

FIGURE 5-20
PRECAMBRIAN SHIELD RESOURCES LIMITED
COAL DIVISION
PICTURE BUTTE COAL PROJECT
A TECHNICAL ASSESSMENT OF PICTURE BUTTE
1983
UNCONFINED COMPRESSION TEST - MUDSTONE

FIGURE 5-20
PB 83-6

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Golder Associates

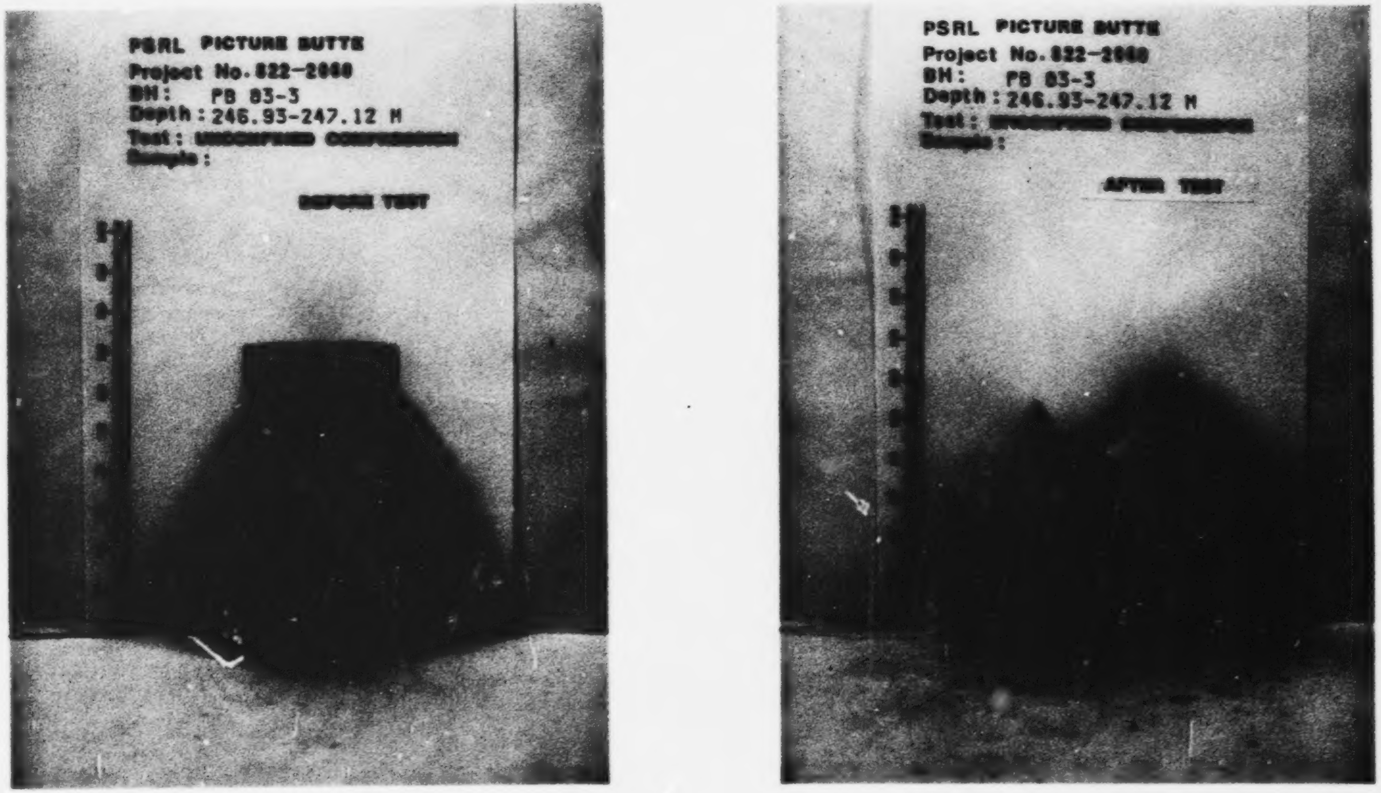
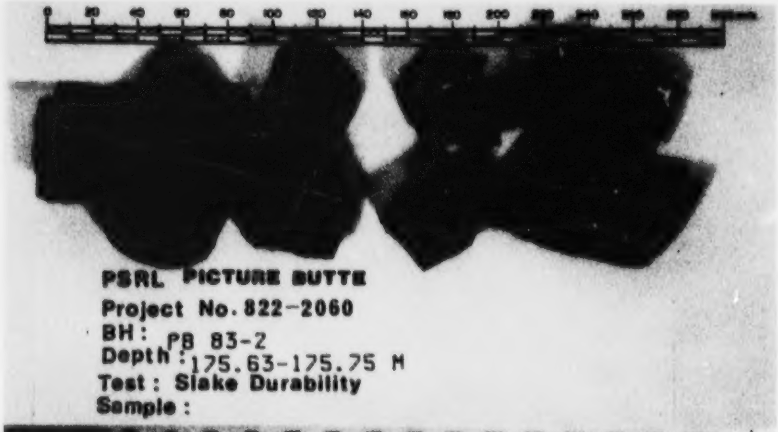

PSRL PICTURE BUTTE
Project No. 822-2080
BH: PB 83-3
Depth: 246.93-247.12 M
Test:
Sample:
BEFORE TEST
PSRL PICTURE BUTTE
Project No. 822-2080
BH: PB 83-3
Depth: 246.93-247.12 M
Test:
Sample:
AFTER TEST

FIGURE 5-21
PB 83-3

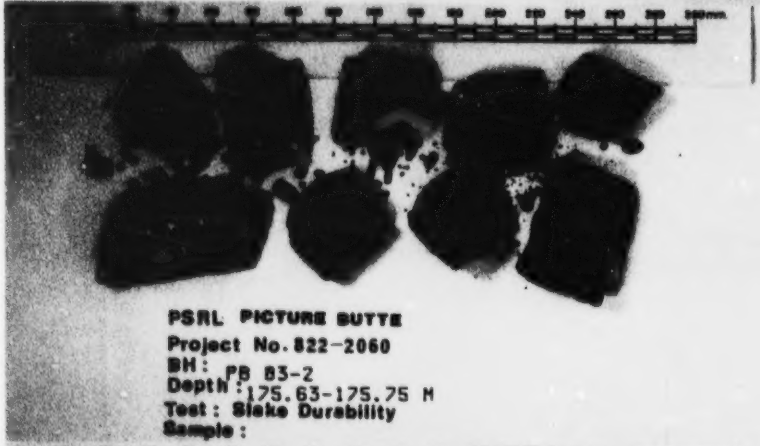
Drillhole PB 83-3

Location 246.9 - 247.1 m
4.7 m below base of GALT SEAM

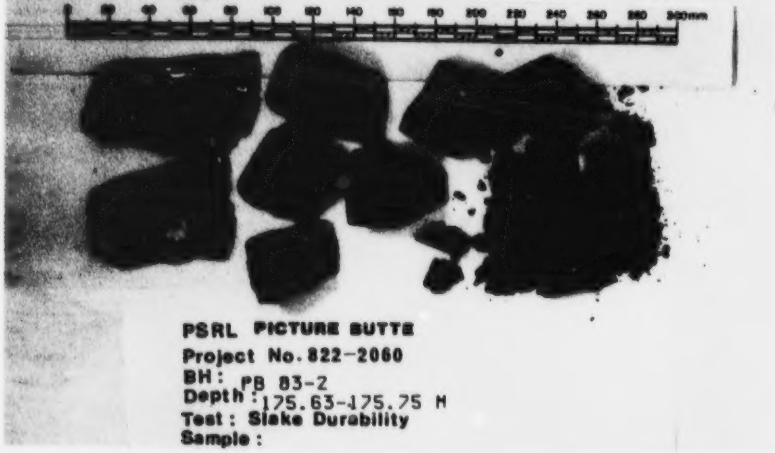
FIGURE 5-21
PRECAMBRIAN SHIELD RESOURCES LIMITED
COAL DIVISION
PICTURE BUTTE COAL PROJECT
A TECHNICAL ASSESSMENT OF PICTURE BUTTE
1983
UNCONFINED COMPRESSION TEST - SANDSTONE


PSRL PICTURE BUTTE
Project No. 822-2060
BH: PB 83-2
Depth: 175.63-175.75 M
Test: Slake Durability
Sample:

SAMPLE AFTER PREPARATION

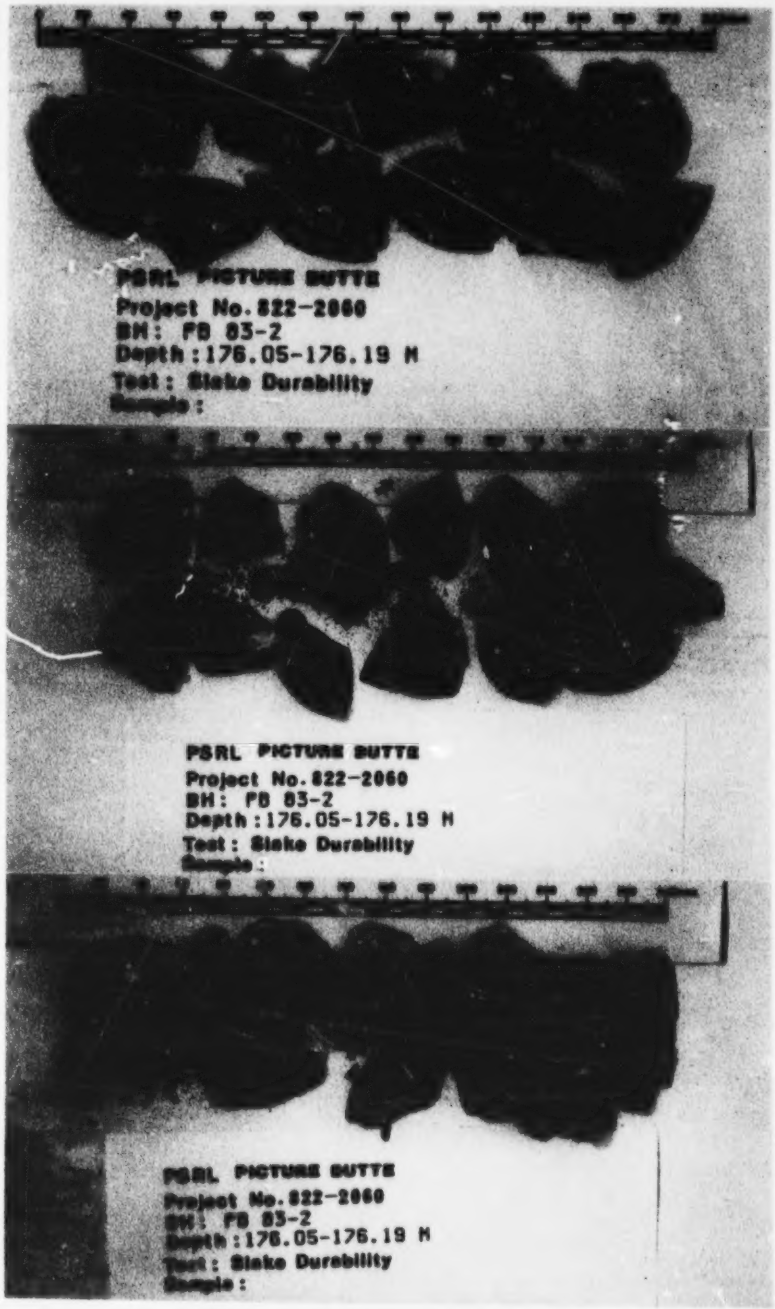

PSRL PICTURE BUTTE
Project No. 822-2060
BH: PB 83-2
Depth: 175.63-175.75 M
Test: Slake Durability
Sample:

AFTER CYCLE No.1


PSRL PICTURE BUTTE
Project No. 822-2060
BH: PB 83-2
Depth: 175.63-175.75 M
Test: Slake Durability
Sample:

AFTER CYCLE No.2
S.D. INDEX 92%

FIGURE 5-22
PRECAMBRIAN SHIELD RESOURCES LIMITED
COAL DIVISION
PICTURE BUTTE COAL PROJECT
A TECHNICAL ASSESSMENT OF PICTURE BUTTE
1983
SLAKE DURABILITY TEST
BASE OF GALT SEAM

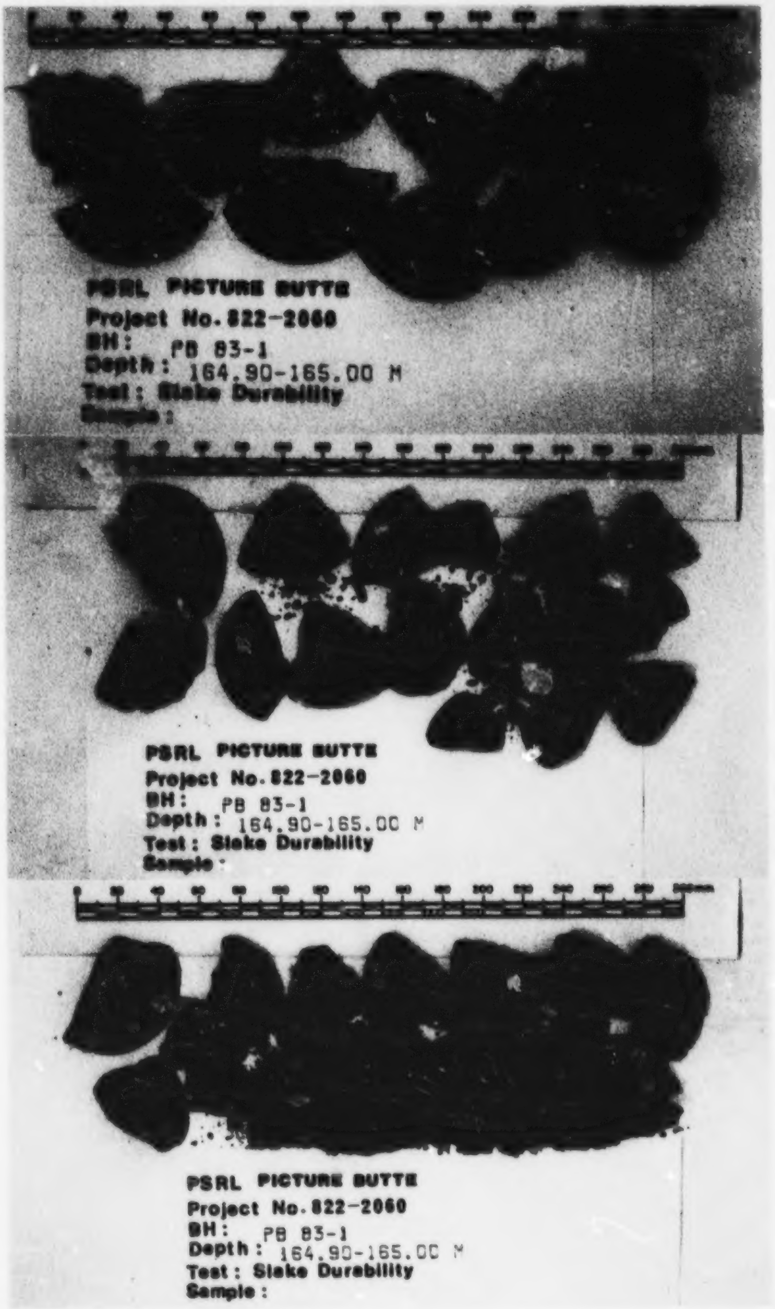

PSRL PICTURE BUTTE
Project No. 822-2060
BH: PB 83-2
Depth: 176.05-176.19 M
Test: Slake Durability
Sample:
PSRL PICTURE BUTTE
Project No. 822-2060
BH: PB 83-2
Depth: 176.05-176.19 M
Test: Slake Durability
Sample:
PSRL PICTURE BUTTE
Project No. 822-2060
BH: PB 83-2
Depth: 176.05-176.19 M
Test: Slake Durability
Sample:

SAMPLE AFTER
PREPARATION

AFTER CYCLE No.1

AFTER CYCLE No.2
S.D. INDEX 97%

FIGURE 5-23
PRECAMBRIAN SHIELD RESOURCES LIMITED
COAL DIVISION
PICTURE BUTTE COAL PROJECT
A TECHNICAL ASSESSMENT OF PICTURE BUTTE
1983
SLAKE DURABILITY TEST
CARBONACEOUS MUDSTONE
AT BASE OF GALT SEAM

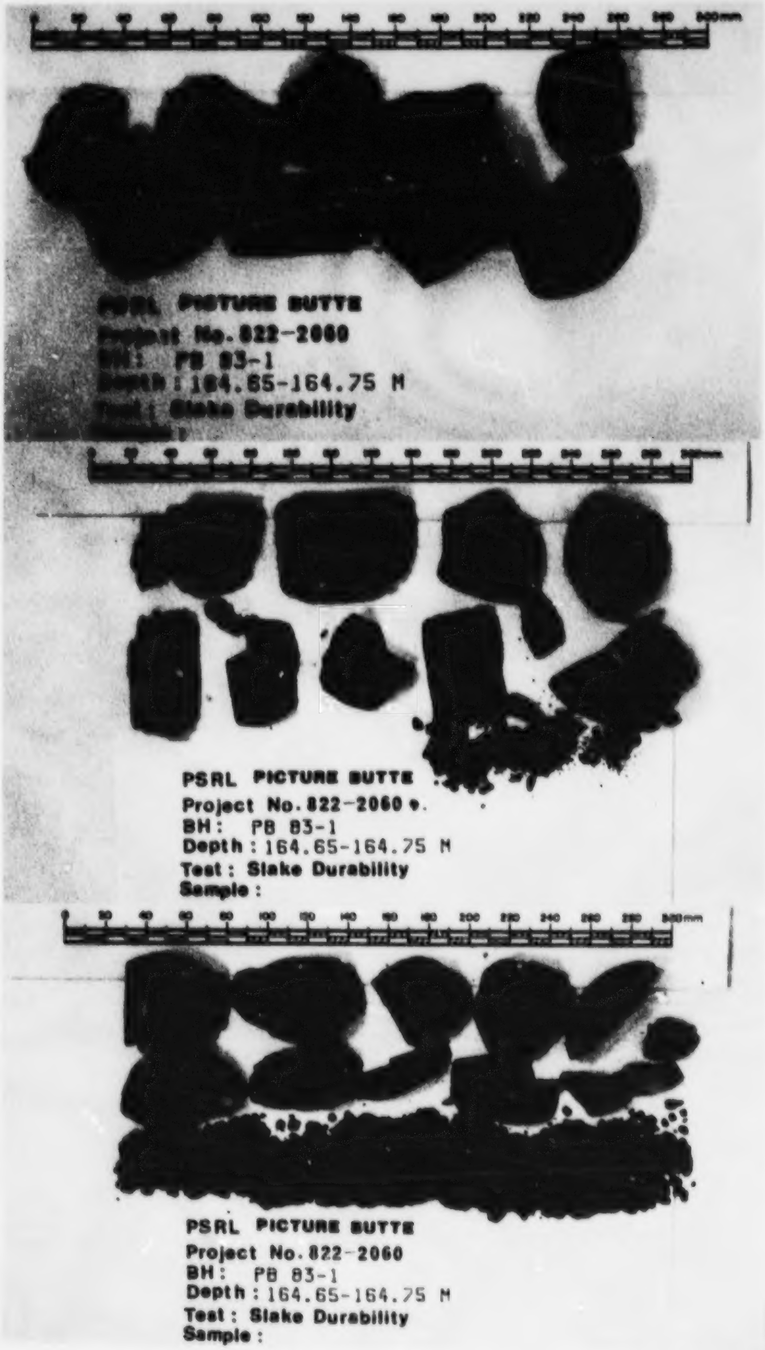

PSRL PICTURE BUTTE
Project No. 822-2060
BH: PB 83-1
Depth: 164.90-165.00 M
Test: Slake Durability
Sample:
PSRL PICTURE BUTTE
Project No. 822-2060
BH: PB 83-1
Depth: 164.90-165.00 M
Test: Slake Durability
Sample:
PSRL PICTURE BUTTE
Project No. 822-2060
BH: PB 83-1
Depth: 164.90-165.00 M
Test: Slake Durability
Sample:

SAMPLE AFTER
PREPARATION

AFTER CYCLE No.1

AFTER CYCLE No.2
S.D. INDEX 81 %

FIGURE 5-24
**PRECAMBRIAN SHIELD RESOURCES LIMITED**
**COAL DIVISION**
PICTURE BUTTE COAL PROJECT
A TECHNICAL ASSESSMENT OF PICTURE BUTTE
1983
SLAKE DURABILITY TEST
MUDSTONE
0.2 m BELOW BASE OF GALT SEAM


0 20 40 60 80 100 120 140 160 180 200 220 240 260 280 300mm
PSRL PICTURE BUTTE
Project No. 822-2060
BH: PB 83-1
Depth : 164.65-164.75 M
Test : Slake Durability
Sample :
PSRL PICTURE BUTTE
Project No. 822-2060
BH: PB 83-1
Depth : 164.65-164.75 M
Test : Slake Durability
Sample :
0 20 40 60 80 100 120 140 160 180 200 220 240 260 280 300mm
PSRL PICTURE BUTTE
Project No. 822-2060
BH: PB 83-1
Depth : 164.65-164.75 M
Test : Slake Durability
Sample :

SAMPLE AFTER
PREPARATION

AFTER CYCLE No.1

AFTER CYCLE No.2
S.D. INDEX 97%

FIGURE 5-25
PRECAMBRIAN SHIELD RESOURCES LIMITED
COAL DIVISION
PICTURE BUTTE COAL PROJECT
A TECHNICAL ASSESSMENT OF PICTURE BUTTE
1983
SLAKE DURABILITY TEST
CARBONACEOUS MUDSTONE
0.1 m BELOW BASE OF GALT SEAM

# PICTURE BUTTE COAL PROJECT
# A TECHNICAL ASSESSMENT OF PICTURE BUTTE
# 1983

## SECTION 6 - GEOTECHNICAL CORRELATION

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| 6.2.1 Structural Fabric | 6-1 |
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6-2 1981 Test Results - Slake Durability, Calcite Content, Moisture Content and Atterberg Limits
6-3 Test Results - X-Ray Diffraction
6-4 Summary of Geotechnical Data

# SECTION 6 - GEOTECHNICAL CORRELATION

## 6.1 GENERAL APPROACH

Details of the geotechnical/strata control studies at Kipp were presented in our Report AR-61A dated January 1983, whilst Report AR-61B presented the geotechnical data previously acquired at Picture Butte and from the 1982 Kipp Trial Mining Program. In that study, the similarities and/or differences in the available data were identified and evaluated, and preliminary conclusions were drawn.

Subsequently, the 1983 Geotechnical Program has been carried out, and all the data has been re-evaluated in order that predicted roof and floor behaviour during potential mining at Picture Butte can be extrapolated from conditions encountered during the TMP.

The discussion is divided stratigraphically into roof, Galt Seam and floor strata. A summary of pertinent geotechnical parameters from Picture Butte 1981 and 1983 and Kipp 1982 is given in Table 6-4.

## 6.2 ROOF STRATA

### 6.2.1 Structural Fabric

Bedding break intervals recorded for the immediate roof strata during the 1983 Picture Butte drilling program generally range from 0.1 m to 0.5 m in mudstones and are classified as being moderately closely spaced. In the rider seams, intervals of approximately 0.05 m were recorded. Considering the subjective nature of this parameter, these results are in agreement with observations made during the 1981 Picture Butte investigation where values from 0.05 m to 0.3 m were reported.

The bedding break spacing recorded in core obtained during the Kipp TMP generally varied from 0.1 m to 0.5 m for the mudstones and was approximately 0.05 m for coal, and are therefore consistent with values reported during the 1983 Picture Butte geotechnical studies.

RQD values reported for the immediate roof in the 1983 program range from 65% to 100%, but generally vary from 90% to 100% with the exception of short coal intervals (RQD - 0%). During the 1981 Picture Butte investigation RQD values were generally 90%. This is in close agreement with observations made at Kipp, where RQD values approach 100% within 2 m of the top of the Galt Seam. In all cases RQD values are almost solely derived from bedding breaks.

In core from both Picture Butte and Kipp, there is little evidence of intense jointing, shearing or other tectonic disturbance. The absence of pronounced jointing in the core from Picture Butte and in the exposed roof at Kipp indicates that the structural fabric of the roof rocks at Picture Butte will be similar to the roof rocks encountered during the TMP at Kipp.

### 6.2.2 Rock Strength

Compressive strength values obtained from tests on mudstone samples taken in the 1983 Picture Butte program vary from approximately 8 MPa to 29 MPa with a mean of approximately 16 MPa, (Table 5-4). Roof mudstone samples from the 1981 Picture Butte study reported strength values ranging from 9 MPa to 14 MPa with a mean value of approximately 10 MPa, (Table 6-1). Values recorded by Dames and Moore in 1979 at Kipp were approximately 35 MPa. As all surface drilling was performed by the same driller with the same equipment, it is reasonable to conclude that the roof mudstones at Kipp are significantly stronger than the equivalent roof mudstones at Picture Butte. Compressive strength tests made on mudstone roof strata during the TMP gave strength values of 42 MPa to 56 MPa confirming this conclusion.

The compressive strength of carbonaceous mudstone strata encountered in the roof at Picture Butte appears to be only slightly lower than that of mudstone. The strength of the ironstone or ferruginous siltstone bands varies widely from approximately 21 MPa in Drillholes PB 81-24 and PB 81-29 (Table 6-1) to 114 MPa in PB 83-1 (Table 5-4). At Kipp a value of approximately 82 MPa was recorded for siltstone strata in the roof. It appears, therefore, that these ironstone bands are the strongest units in the roof strata at both Kipp and Picture Butte.

### 6.2.3 Material Properties

Atterberg limits determined on a typical Bearpaw mudstone sample from Picture Butte indicate a 'clay-rock' of medium plasticity. Similar results were obtained on immediate roof samples (Oldman Formation) from the Kipp Mine. The calcite content in roof strata at Kipp is low (less than 1.5%). Similarly, calcite contents in the mudstone roof strata in the central Picture Butte area are also low (generally less than 0.6%), but slightly higher for Bearpaw mudstones (less than 1.2%). These test results indicate a minimal contrast between the mudstones of the Oldman and Lower Bearpaw Formations, and suggest that the mudstones of both formations should react similarly to mining.

## 6.3 GALT SEAM

### 6.3.1 Structural Fabric

Bedding break intervals in the Galt Seam recorded in Drillholes PB 83-1 through PB 83-6 range from 0.1 m to 0.9 m, but most frequently vary from 0.15 m to 0.5 m, moderately close to close, (Table 5-2). During the 1981 Picture Butte investigation, values were found to vary from 0.05 m to 0.6 m which is consistent with the 1983 results.

RQD measurements carried out for the Galt Seam in Drillholes PB 83-1 through PB 83-6 ranged from 50% to 100%, but most frequently from 80% to 100%. Reported values from the 1981 Picture Butte program indicate a range from 25% to 95%. During the Kipp TMP no RQD parameters were obtained for the Galt Seam, but Dames and Moore (1979) recorded a range of 50% to 75%. Therefore, RQD values at Kipp and Picture Butte appear to be in reasonable agreement.

### 6.3.2 Rock Strength

Results from the 1982 Kipp TMP and the Dames and Moore (1979) investigation reported values of approximately 10 MPa and 9 MPa respectively. The unconfined compressive strength recorded in the Galt Seam in Drillholes PB 83-1 through PB 83-6 vary from 9 MPa to 20 MPa with a mean of approximately 14 MPa. These values confirm the results from the 1981 Picture Butte program, which reported mean value of approximately 17 MPa, and are significantly higher than the values reported at Kipp.

### 6.3.3 Slake Durability

A wide scatter exists in the 1983 test results on the Galt coal, with first cycle values ranging from 96% to 47%, and second cycle values from 90% to 24%, see Table 5-6.

During the Kipp TMP one test yielded 90% and 64% for first and second cycle respectively, and previous testing by Dames and Moore obtained values of 90% and 70% in BH 78-1 and BH 78-2 respectively.

Although only three test results from Kipp are available, these test results indicate that the slaking resistance of the coal at Kipp is higher than at Picture Butte.

## 6.4 FLOOR STRATA

### 6.4.1 Structural Fabric

In the 1983 geotechnical program, bedding break intervals recorded in typical floor mudstones from Drillholes PB 83-1 through PB 83-6 vary from 0.1 m to more than 1 m, but generally range from 0.15 m to 0.6 m. Carbonaceous mudstones appear to have wider bedding break intervals between 0.05 m to 0.1 m. For siltstones and sandstones this parameter was found to range from 0.6 m to more than 1 m.

The bedding break intervals observed in mudstones in the rock core obtained from geotechnical drilling in the Kipp TMP are in very close agreement with the 1983 bedding breaks recorded for mudstone core.

Values recorded during the 1981 Picture Butte Study appear to be slightly lower (0.01 m to 0.35 m) than values reported in 1983, although it should be noted that the 1981 studies were carried out over a very limited area and with different field personnel. Therefore we do not consider this a significant discrepancy.

RQD values in Drillholes PB 83-1 through PB 83-6 generally vary from 50% to 100%. RQD values reported in 1981 generally vary from 50% to 75%. These values are in general agreement with observations made at Kipp during the TMP (60% to 80%) and during the Dames and Moore investigation (55% to 85%).

It is reasonable to conclude that the behaviour of the floor strata with respect to structural discontinuities will be the same at Picture Butte as at the Kipp Mine.

### 6.4.2 Rock Strength

Unconfined compressive strength values for the different floor strata at Picture Butte obtained during the 1983 and 1981 investigations are shown in Tables 5-5 and 6-1 respectively, and summarized in Table 6-4.

In the 1983 Picture Butte program, the reported strength of the floor mudstones varies from 7.5 MPa to 31 MPa and are in general agreement with results from the 1981 study (7.5 MPa to 22.8 MPa) These values are significantly lower than the strength recorded by Dames and Moore at Kipp (37 MPa) and by Golder in the TMP (mean value 37.5 MPa). The same drilling equipment and operator was used during all the surface geotechnical programs (Dames and Moore 1979, Golder 1981 and 1983). It is therefore reasonable to conclude that the strength of the mudstone in the floor at Picture Butte is less than at Kipp.

The general observation made for Kipp is that no significant difference in strength exists between mudstones and carbonaceous mudstones in the seam floor (31 MPa to 52 MPa). However, this is not the case at Picture Butte, where a lower range of strength values were reported for carbonaceous mudstones (1.5 MPa to 22 MPa from three samples in 1981 and less than 5 MPa on one sample in 1983).

Strength of the siltstone encountered at Picture Butte of approximately 40 MPa is in close agreement with results obtained for samples taken during the underground drilling program at Kipp.

The strength of the sandstone strata at Picture Butte reported in the 1981 study was approximately 35 MPa which is consistent with the results from the 1983 program (35 MPa to 70 MPa). These values are slightly higher than those previously reported by Dames and Moore but are consistent with results from sandstone floor strata recovered from diamond drilling at Kipp during the 1982 TMP, where values of approximately 55 MPa were recorded.

### 6.4.3 Slake Durability

Test results from the 1983 Picture Butte Geotechnical Program indicate that the mudstones at Picture Butte have a higher resistance to slaking than previously anticipated. First cycle values range from 97% to 92%, whilst second cycle values range from 92% to 76%, see Table 5-6. These results, compare favourably with the slake durability test results (second cycle) from Kipp (57% in 4 tests, Golder 1982) and indicate a significantly higher resistance to slaking than was indicated by previous results from Picture Butte (see Table 6-2) which indicated that the resistance to slaking of the mudstones at Picture Butte could be a serious constraint to mining. It is possible that the 1981 test samples from Picture Butte were adversely affected by the surface drilling procedure, whereas samples from Kipp were relatively undisturbed. Also, the samples tested during the 1981 program were from a very limited area. It is therefore reasonable to accept the 1983 test results as being more representative of the resistance to slaking of the floor mudstones at Picture Butte.

Slake durability test results for carbonaceous mudstone samples taken during the TMP indicate slightly lower 2nd cycle values (approximately 55%), whereas results from the 1983 program indicate second cycle values with a mean of 78%. These results indicate that there is generally no significant difference between the slake durability of mudstone and carbonaceous mudstone at either Kipp or Picture Butte. At Picture Butte and at Kipp both units appear to have a similar resistance to slaking.

These results indicate that a mine floor established at Picture Butte on mudstone or carbonaceous mudstone will have similar ground conditions as a result of slaking and material breakdown to those at Kipp, provided that the water conditions are the same.

### 6.4.4 Material Properties

Atterberg limits determined on floor mudstone samples during the 1981 and 1983 Picture Butte programs were found to be very similar, with plastic limits varying from 21% to 39% and from 28% to 38%, see Tables 6-2 and 5-6. These results are consistent with two test results obtained during the Kipp TMP (plastic limits approximately 29%). Atterberg limits were obtained for the bentonite bands in the floor strata in Drillhole PB 83-1, the lowest plastic limit recorded being 27%, with very high plasticity indices of 94% and 121%.

## 6.5 CLAY MINERALOGY

The results of spectrographic analyses on samples from the Kipp Mine (Table 6-3), indicate that the stability of mine openings will be dictated by both mineralogical and physical controls.

The X-ray diffractograms of mudstones from the 1983 Picture Butte program (Table 5-9) are consistent with those from similar strata at Kipp, with major amounts of clay minerals, of which montmorillonite is dominant.

From the similarity of results it is concluded that any potential ground control problems at Kipp that could be attributed to the high montmorillonite content in the strata would also be experienced at Picture Butte.

As montmorillonites generally have very high liquid limit values, it will be essential that moisture levels be maintained at a minimum level to prevent ground control problems caused by swelling and desiccation of floor and roof strata respectively during mining operations at Picture Butte.

## 6.6 CONCLUSIONS

The conclusions derived from the geotechnical evaluation can be summarized as follows:

a. The structural fabric of the seam sequence appears to be similar at Picture Butte and Kipp, and the behaviour of the floor and roof strata with respect to structural discontinuities will be the same.

b. Although the mudstones of the Oldman and Lower Bearpaw Shale Formations have similar material properties at both Kipp and

Picture Butte, the roof strata at Picture Butte appears to be weaker than at Kipp.

c. Laboratory test data indicates that the unconfined compressive strength of the Galt Seam at Picture Butte is higher than at Kipp.

d. The strength of the mudstones in the floor strata at Picture Butte appears to be less than at Kipp.

e. Laboratory test results from the 1983 Geotechnical Program indicate that both the mudstones and carbonaceous mudstones at Picture Butte will probably have a similar resistance to slaking (mechanical breakdown) as those exposed at Kipp.

# TABLE 6-1

# PICTURE BUTTE COAL PROJECT

# A TECHNICAL ASSESSMENT OF PICTURE BUTTE

# 1983

## TEST RESULTS - UNIAXIAL COMPRESSIVE STRENGTH (1981 STUDY)

| SAMPLE # | DRILLHOLE # | DEPTH (m) | DISTANCE ABOVE (+) OR BELOW (-) GALT (m) | UNIAXIAL COMPRESSIVE STRENGTH (MPa) |
|---|---|---|---|---|
| **Galt Coal** | | | | |
| 4 | PB81-25 | 85.6 | - | 17.6 |
| 10 | PB81-26 | 83.9 | - | 17.9 |
| 23 | PB81-29 | 81.7 | - | 14.7 |
| **Mudstone (Roof - Oldman)** | | | | |
| 11 | PB81-27 | 81.9 | +3.9 | 9.2 |
| 21 | PB81-29 | 80.8 | +0.3 | 10.8 |
| 9 | PB81-26 | 82.2 | +1.1 | 9.5 |
| 28 | PB81-29 | 79.9 | +1.2 | 10.2 |
| 12 | PB81-27 | 84.1 | +1.7 | 9.0 |
| 20 | PB81-29 | 78.8 | +2.3 | 6.6 |
| 1 | PB81-24 | 75.8 | +3.2 | 13.5 |
| 19 | PB81-29 | 77.7 | +3.4 | 8.9 |
| **Mudstone (Roof - Bearpaw)** | | | | |
| 3 | PB81-24 | 79.9 | +4.5 | 6.1 |
| 2 | PB81-24 | 77.6 | +6.8 | 5.8 |
| 11 | PB81-26 | 76.3 | +7.0 | 9.2 |
| 18 | PB81-29 | 76.$ | +4.7 | 8.6 |
| **Ferruginous Siltstone (Roof)** | | | | |
| 26 | PB81-29 | 79.7 | +1.4 | 20.8 |
| 26 | PB81-24 | 77.2 | +1.8 | 20.8 |
| **Carbonaceous Mudstone (Floor)** | | | | |
| 13 | PB81-27 | 89.7 | -0.1 | 1.5 |
| 14 | PB81-27 | 90.0 | -0.4 | 4.6 |
| 24 | PB81-29 | 82.8 | -0.2 | 22.0 |
| **Mudstone (Floor)** | | | | |
| 25 | PB81-29 | 83.4 | -0.3 | 7.5 |
| 22 | PB81-29 | 83.8 | -0.8 | 13.1 |
| **Siltstone (Floor)** | | | | |
| 6 | PB81-25 | 87.1 | -1.2 | 40.3 |
| 10A | PB81-26 | 86.3 | -1.5 | 22.8 |
| **Sandstone (Floor)** | | | | |
| 15 | PB81- | 90.9 | -1.2 | 34.5 |

# TABLE 6-2

# PICTURE BUTTE COAL PROJECT

# A TECHNICAL ASSESSMENT OF PICTURE BUTTE

# 1983

## TEST RESULTS - SLAKE DURABILITY, CALCITE CONTENT, MOISTURE CONTENT, AND ATTERBERG LIMITS

| SAMPLE # | LOCATION | DRILL HOLE # | DISTANCE ABOVE (+) OR BELOW (-) GALT (m) From | To | SLAKE DURABILITY (% RETAINED) 1st CYCLE | 2nd CYCLE | CALCITE CONT. (%) | ATTERBERG LIMITS LIQUID (%) | PLASTIC (%) | PLAST. INDEX (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| **Mudstone (Roof - Bearpaw)** | | | | | | | | | | |
| 2 | PB 81-25 | 78.1 | +6.3 | | | | | 41 | 24 | 17 |
| 17 | PB 81.29 | 50.3 | +30.8 | | | | 1.0 | | | |
| | ST 3 | 55.7 | | | | | 1.2 | | | |
| | ST 3 | 54.6 | | | | | 1.0 | | | |
| | ST 3 | 53.1 | | | | | 1.1 | | | |
| **Mudstone (Roof - Oldman)** | | | | | | | | | | |
| 21 | PB 81-29 | 80.8 | +3.0 | | | | 2.4 | | | |
| 9 | PB 81-26 | 81.9 | +1.4 | | | | 0.6 | | | |
| 26 | PB 81-24 | 77.2 | +1.8 | | | | 0.3 | | | |
| 11 | PB 81-27 | 81.9 | +3.9 | | | | 0.3 | | | |
| Gouge (Roof) | PB 81-25 | 81.8 | +2.6 | | | | | 67 | 30 | 37 |
| **Carbonaceous Mudstone (Floor)** | | | | | | | | | | |
| 5 | PB 81-25 | 86.0 | -0.1 | | 68 | 32 | | | | |
| 24 | PB 81-29 | 82.9 | -0.2 | | 83 | 58 | | | | |
| 13 | PB 61-27 | 89.7 | -1.5 | | 70 | 27 | | | | |
| **Mudstone (Floor)** | | | | | | | | | | |
| 25 | PB 81-29 | 83.4 | -0.8 | | 28 | 0 | 0.1 | 73 | 39 | 34 |
| 22 | PB 81-29 | 83.8 | -1.2 | | 82 | 58 | 0.2 | 52 | 21 | 31 |
| 14 | PB 81-27 | 89.9 | -2.9 | | 0 | 0 | | 76 | 22 | 54 |
| **Siltstone (Floor)** | | | | | | | | | | |
| 10A | PB 81-26 | 86.2 | -1.5 | | 96 | 93 | 2.1 | | | |

# TABLE 6-3

# PICTURE BUTTE COAL PROJECT

# A TECHNICAL ASSESSMENT OF PICTURE BUTTE

# 1983

# TRIAL MINING PROGRAM - KIPP MINE

## TEST RESULTS X-RAY DIFFRACTION AND PETROGRAPHIC ANALYSES

| Sample # | Distance (m) Above(+) or Below(-) Galt Seam | Quartz | Plagio- clase | Carbon- aceous Fragments | Illite/ Muscovite | Kaolinite | Montmoril- lonite | Calcite |
|---|---|---|---|---|---|---|---|---|
| SA 1 | +0.35 | -(3%)[1] | -(3%)[1] | 3%[1] | - | - | - | - |
| SA 2 | +0.25 | +(25%)[1] | +(25%)[1] | 10%[1] | -(2%)[1] | - | + | |
| SA 5 | Parting** | | | 3% | | | ++ | |
| SA 18 | -0.33 to -0.45 | (3%)[1] | (3%)[1] | 20%[1] | - | - | ++ | |
| SA 19 | -0.05 to -0.25 | +(1%)[1] | -(1%)[1] | 20% | - | - | ++ | |
| SA 38 | _0.05 to -0.27 | (2%) | | 30%[1] | -(½%)[1] | - | ++ | |
| SA 39 | -0.27 to -0.35 | (5%)[1] | (5%)[1] | 25%[1] | - | | ++ | |
| SA 77 | +3.0 (824) | + | - | | - | - | + | |
| SA 78 | +6.2 (82-4) | + | - | | - | - | + | |
| SA 79 | +11.2 (82-4) | + | tr | | - | - | + | |

++ = dominant

+ = major

- = minor

* = not x-rayed for

[1] Visually estimated mode based on framework only. Percentage shown for quartz or plagioclase is the combined quartz and plagioclase content of the framework grains only. Percentage shown is for framework muscovite only.

** 1.3 m above base of Galt

# TABLE 6-4
# PICTURE BUTTE COAL PROJECT
# A TECHNICAL ASSESSMENT OF PICTURE BUTTE
# 1983

## SUMMARY OF GEOTECHNICAL DATA

| Horizon** | Location | Compressive Strength (MPa) | Slake Durability* | | Moisture Content (%) | Atterberg Limits | | | Free Swell (%) | Bulk Density |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1st Cycle (%) | 2nd Cycle (%) | | Liquid (%) | Plastic (%) | Plastic Index (%) | | |
| ROOF | | | | | | | | | | |
| 0 to 1.5 m above Galt Seam | Kipp 1982 | 42 | N/R | N/R | N/R | 37 to 48 | 20 to 26 | 17 to 23 | 1 to 2 | N/R |
| | PB 1981 | 10 to 21 | N/R | N/R | N/R | N/R | N/R | N/R | N/R | N/R |
| | PB 1983 | 8 to 29 | 79 to 88 | 20 to 70 | 9 to 9 | N/R | N/R | N/R | N/R | N/R |
| > 1.5 m above Galt Seam | Kipp 1982 | 42 to 82 | N/R | N/R | N/R | N/R | N/R | N/R | 1 to 5 | 2.39 to 2.92 |
| | PB 1981 | 6 to 21 | N/R | N/R | N/R | 41 to 67 | 24 to 30 | 17 to 37 | N/R | N/R |
| | PB 1983 | 14 to 114 | N/R | N/R | 8 to 9 | N/R | N/R | N/R | N/R | 3.17 |
| GALT SEAM | Kipp 1982 | 9 to 11 | 89 | 64 | N/R | N/A | N/A | N/A | N/A | N/R |
| | PB 1981 | 15 to 18 | N/R | N/R | N/R | N/A | N/A | N/A | N/A | N/R |
| | PB 1983 | 9 to 20 | 47 to 96 | 24 to 90 | N/R | N/A | N/A | N/A | N/A | N/R |
| FLOOR | | | | | | | | | | |
| 0 to 0.5 m below Galt Seam | Kipp 1982 | 27 to 44 | 30 to 97 | 23 to 57 | 6 to 10 | 38 to 56 | 23 to 30 | 9 to 21 | 4 to 12 | 1.58 to 2.23 |
| | PB 1981 | 2 to 22 | 68 to 83 | 32 to 58 | N/R | N/R | N/R | N/R | N/R | N/R |
| | PB 1983 | N/R | 75 to 98 | 45 to 97 | N/R | 55 | 28 | 27 | 1 to 4 | 1.51 to 2.38 |
| > 0.5 m below Galt Seam | Kipp 1982 | 25 to 54 | 94 to 96 | 89 to 93 | N/R | N/R | N/R | N/R | N/R | 2.42 to 2.46 |
| | PB 1981 | 13 to 35 | 0 to 96 | 0 to 58 | N/R | 52 to 76 | 22 to 39 | 31 to 54 | N/R | N/R |
| | PB 1983 | 5 to 70 | 91 to 96 | 75 to 89 | 8 to 26 | 71 to 148 | 27 to 48 | 39 to 129 | 0 to 20 | 1.94 to 2.46 |

* % Retained
** Ranges of values for all rock types within this interval
N/R Not Recorded
N/A Not Applicable

TABLE 6-4

# PICTURE BUTTE COAL PROJECT
# A TECHNICAL ASSESSMENT OF PICTURE BUTTE
# 1983

## SECTION 7 - UNDERGROUND MINING AT PICTURE BUTTE

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# SECTION 7 - UNDERGROUND MINING AT PICTURE BUTTE

## 7.1 GENERAL

Underground mine design is site specific - there is no simple, standard design. Assumptions or deductions made about relevant design criteria must be carefully weighed - if too optimistic then planned production goals are not achieved; if too pessimistic the mine is never developed.

The constraining factors considered for mine design are of two types: fixed parameters (eg: geology, water, gas, old workings, etc.) and variable parameters (eg: design of roadways, mining methods, mine layout support systems, services, etc.).

This section deals with the impact of the 'fixed' parameters as determined in this study on the variable design parameters at Picture Butte.

## 7.2 GROUNDWATER

Water released into the mine from the coal seam or overburden could have a detrimental effect on the behaviour of the exposed floor rocks at Picture Butte, and could restrict the rate of longwall advance.

Available ground water data in the Kipp-Picture Butte area has been studied. There is only limited information with regard to hydraulic conductivities of the various strata. However certain conclusions have been made and are based upon hydrologic testing and monitoring of piezometer installations across the Picture Butte Lease Area, and on hydrological reports of the Lethbridge area.

The water levels across the Picture Butte area define a piezometric surface which decreases in elevation from northwest to southeast, indicating a flow toward the southeast. In the vicinity of PB 80-11 and PB 80-13, the piezometric surface and the Galt Seam are almost coincident, indicating that to the southeast of this location the seam is either dry, or in an unconfined condition with gravity flow down-dip to the northwest. The former is considered the most probable as seepage from the Galt Seam is reportedly not observed in exposures along the Oldman River or in Piyami Coulee.

A pre-glacial buried channel with associated highly permeable Saskatchewan gravel and sand deposits is known to exist to the north and east of the Picture Butte lease area, but does not traverse the PSRL property. The existence of any major buried channels or aquifers lying above the Galt Seam across the Picture Butte property has not been indicated by drilling and is considered extremely unlikely.

At Picture Butte, the overall permeability of the glacial overburden will be very low, in the order of $1 \times 10^{-10}$ m/s. Isolated gravel bands may have higher permeability, but the water in them will be confined by almost impermeable materials. The low permeability of the bedrock overlying the Galt Seam should minimize any ground water flow from the bedrock/glacial overburden contact into development roadways. Above the extracted longwall panels, mining will result in caving and fracturing of the roof strata. However, even if the fractures induced by mining penetrate the bedrock/glacial overburden contact, it is not anticipated that inflows will pose serious problems because of the clayey/silty nature of the till, and its expected very low permeability.

It is probable that the Galt Seam, with its well-defined cleat system, has a significantly higher permeability than the enclosing strata. Previous hydrogeologic data suggested that the Galt seam at Kipp was water bearing, and that it was under considerable pressure, indicating a 'confined aquifer' condition. However, water was not encountered when the Kipp shaft penetrated the seam, and it is significant that water seepage problems were not encountered during recent trial mining. Also, there are no records of excessive inflows in the Galt No. 8 Mine and water pressures within the coal seam were not encountered during the 1983 drilling program. It is reasonable to assume that the overall ground water regime at Picture Butte will be similar to Kipp, and that the hydrologic characteristics of the Galt Seam will be similiar. The lack of ground water flow through the coal seam, or from the overlying strata in the test mine, is therefore significant.

The extremely low permeability of the Bearpaw Shale formation, and the strata enclosing the Galt Seam indicate that groundwater flow from these strata into the mine will not be a problem. However, as a part of the overall feasibility study, pumping tests may be required over the full section of the overburden, and would enable a more detailed assessment of potential inflows, and to confirm whether or not groundwater in the overlying glacial material should be considered as a constraint to mining and/or shaft sinking at Picture Butte.

## 7.3 FLOOR CONDITIONS

The physical properties of the floor strata play a very important part in the choice of longwall face equipment and method of roof support in roadways for a successful mining operation.

The results of slake durability and free swelling tests indicate that operating problems caused by the swelling and deterioration of immediate floor strata would not be experienced unless the floor is exposed to wet conditions over a period of time. This applies both at the working face and in roadways.

Geotechnical data comparisons of the engineering properties of floor mudstones between Kipp and Picture Butte indicate similar slake durability indices but lower compressive strength values in the Picture Butte area. Problems are, therefore, not anticipated with trackless equipment for roadway development, unless water is present over a period of time. Since floor heave was not detected during the Kipp TMP except in I South, where it amounted to less than 5 cm, rail transport for men and materials and floor supported belt transport of coal could be considered for any future mine planning in the Picture Butte area.

The geologic correlation indicates that whichever seam splits are mined at Picture Butte, the floor will be established on either carbonaceous mudstone or mudstone similar to that encountered at Kipp. Laboratory test results indicate that the plastic limit of strata is much higher than the in situ material moisture contents. We anticipate that the hydrogeologic conditions at Picture Butte will be the same as at Kipp and the floor strata at Picture Butte should, therefore, behave in the same manner as during the TMP. The only appreciable quantities of water encountered at Kipp came from water line breaks in headings. This water on the floor resulted in posts sinking into the floor, requiring repairs to the sets. In general it was found that secondary services of water from dust suppression on the continuous miner and from stoper bolting operations, did not contribute to floor degradation at Kipp. The 1983 Geotechnical studies at Picture Butte did not indicate that high water pressures exist near the Galt Seam. However, the possibility of water problems cannot be completely precluded and should be considered during detailed mine design studies.

## 7.4 ROOF STABILITY

Roof stability in general refers to the stability of the immediate roof and the time duration that it may be left unsupported, either in roadways or at the operating face. There are many factors that contribute to roof stability: mining height, strata properties, structural discontinuities, etc.

### 7.4.1 Longwall Face Support

To determine the longwall face support requirements, it is necessary to estimate the thickness of the immediate roof ie: that portion of the roof that detaches from the main roof strata, deflects downward and requires support soon after the underlying coal is extracted. As longwall face supports only counter loads imposed by the immediate roof (and not the entire overburden sequence) over brief periods of time it is only this immediate roof which requires support. The thickness of this zone is usually estimated to be in the range of two to three times the seam height.

The overall caving characteristics of the roof are influenced by the local geology. The mudstone/shale roof above the Galt Seam at Picture Butte will cave readily, as illustrated by the roof fall at Kipp in I South. While the height of the roof cave in a roadway does not necessarily reflect the height of a caving zone behind a longwall panel, the nature of the caved material does indicate how the roof material will behave when caved in gob areas. From the inspection of the caved roof material in I South, a 'bulking factor' of 30% to 35% is estimated for this type of strata.

The magnitude of abutment pressures caused by cantilevered roof beams depends on the length and thickness of the immediate roof strata that overhangs the gob area behind the face supports. The shale and mudstone that comprise the immediate roof at the Picture Butte property should cave readily into extracted areas almost immediately after advance of the face supports. The development of long unsupported roof spans in the gob areas that could impose excessive abutment pressures on the longwall face are not anticipated. Caving characteristics can, therefore, be considered as favourable for longwall mining at Picture Butte.

The thickness of bedrock overlying the coal seams is important for both roof stability and face support, and the potential for groundwater inflows into the mine through fractured ground above mined out areas. There is, therefore, a minimum thickness of bedrock overlying the seam that must be considered. The height of the induced 'fracture zone' above mined-out longwall panels may vary between 25 and 40 times the extracted seam thickness. If the conservative estimation is assumed, the height of the fracture zone above the thickest anticipated seam extraction (3.8 m) would be approximately 150 m. If the mining section were restricted to 1.5 m, the height of the fracture zone would be approximately 60 m. Similarly, using the lower factor, the height of the fracture zone would vary between 95 m and 40 m for the respective extracted seam sections. Although there is a large degree of ambiguity in this calculation, it is reasonable to assume that the induced 'fracture zone' over longwall panels will penetrate the bedrock/overburden contact across part of the Picture Butte property.

There is a gradual decrease in thickness of rock overburden above the Galt Seam towards the eastern boundary of the Picture Butte lease area, and beneath Piyami Coulee. It is possible, therefore, that some areas of the property will not be capable of being mined using the longwall method. Alternative mining methods may have to be considered in any feasibility or detailed design studies for areas of thin rock overburden and irregular fault bounded blocks.

Records indicate that the glacial material in the area is generally silty, and will have a very low permeability, and it is reasonable to assume that serious water inflow from the glacial overburden will not occur through the fractured roof strata. If the results of pump tests and/or early mining operations indicate that groundwater inflows into gob areas from the glacial overburden could be significant, it may be necessary to limit longwall mining to areas with a thicker bedrock roof section.

### 7.4.2 Roadway Support

In general it was found at Kipp that a coal roof resulted in better roof conditions, with less roof spalling and bed separation than when a shale roof was attempted. Even though roadway orientation and direction of drivage had an effect on the roof conditions it is recommended that all rectangular roadway drivage at Picture Butte be done under a coal roof. This is particularly important as the limited available geotechnical data indicates weaker mudstones in the roof strata at Picture Butte area than encountered at Kipp.

The experience of extensive roof support changes and repairs where the mining-roof horizon was altered, indicates that similar roof horizon changes at Picture Butte should be given more support with stronger beams or closer support spacing. The number of roof horizon changes in developing a mine design should be kept to a minimum.

The coal at Kipp was found to be strong and did not give sloughing problems. Rib pressure on posts was noticed on 2 to 3 sets only at the 1 South/5 West junction and this condition was taken to be localized in nature. It is assumed from these observations that there will be no rib pressure problems at Picture Butte. The small amount of rib coal sloughing that did occur was in 3 West which was oriented along the cleat direction. Similar sloughing may occur in roadways oriented along the cleat in Picture Butte.

## 7.5 CONSTRAINTS TO EQUIPMENT SELECTION

Expansion and/or physical breakdown of the floor strata will decrease its supporting capacity. Floor penetration of face supports and conveyor pans at Picture Butte will depend upon the lithology of the floor strata and moisture conditions at the face.

Because poor floor conditions over parts of the Picture Butte area were indicated by the 1981 geotechnical test results, longwall supports should be selected to provide adequate stability. Floor and roof load distribution for the face supports should be considered, not only under static conditions, but also under dynamic, ie: operating conditions. Pressure distributions of the canopy and base for different supports are available from equipment manufacturers.

A shield-type support is generally recommended for a potentially weak roof, because the horizontal component exerted by the shield canopy tends to push the immediate roof strata toward the face resulting in more stable conditions. Shield supports are also suitable for seams thicker than 2 m because of their high resistance to tangential forces. With the potential variation in extraction thickness it may be necessary to use more than one size range of face supports throughout the mine.

The selection of face support and material handling systems is dependent upon a series of design parameters (bearing capacity and stability of roof and floor, floor trafficability, etc.) and is beyond the scope of this report. Methods of calculating support requirements from rock properties and geologic data are not exact, however several factors affecting face support equipment have been identified during this study, and should be referred to equipment manufacturers when equipment selection studies are undertaken.

## 7.6 IMPLICATIONS TO MINE LAYOUT

Picture Butte lies over 10 km to the north of Kipp. The ground conditions encountered during the TMP at Kipp may not be indicative of the actual conditions at Picture Butte. Based on a stratigraphic correlation and geotechnical interpretation of test data we predict a similarity in ground conditions between the two areas, but this has yet to be proven.

Visual observations during the TMP have indicated higher stresses parallel to the cleat, and it is reasonable to assume that this is also the case for Picture Butte. The pronounced cleat will affect the stability of the coal face; coal worked parallel to the cleat will fall off in large slabs, and working a butt cleat will require more energy to cut the coal. By maintaining a north-south, east-west mine layout, a compromise will be attained for both actual mining of the coal and roadway stability. This will result in longwall faces and long-term entries being developed at approximately 60° to the main cleat, along the weak roof direction; and all gate roads being developed at approximately 30° to the main cleat, along the "good roof" direction. At the present time it is not considered that the location and orientation of gate entries (and therefore panel widths) will be dictated by zones of weakness, joint patterns, or faults, etc. Where a persistent joint set exists, longwall faces aligned exactly parallel or perpendicular to this joint set experience roof control problems. However, the absence of joints observed in the immediate roof strata at Kipp and in drill core from Picture Butte eliminates this as a constraining factor on the choice of longwall face alignment.

Minor faulting as documented in mines within the Lethbridsge area, shows no preferred direction. However, a geologic risk analysis should be included with any potential mine plan when an economic assessment is made.

If detailed hydrogeologic studies such as pump testing indicate that groundwater inflows may be a constraint to mining at Picture Butte, the most favourable longwall extraction would be to the east (up-dip), allowing water to drain off into the gob area. In the longwall retreat method of mining, this would involve the development of gate roads in a down-dip direction. Bed separation and induced ground fracturing above roadways will not be so severe as that above the working longwall face, and it is not anticipated that any water problems will be encountered at the face during development of roadways.

## 7.7 SUBSIDENCE

The land surface is generally used for the production of grain with some cattle grazing, and is traversed by an irrigation system consisting of ditches and canals, as well as by gas pipelines. No major structures exist across the property.

It is generally accepted that variations in the type of stratum between the coal seam and the ground surface have little effect on the maximum amount of subsidence. However, the nature of the surficial deposits will affect the shape and surface effects of subsidence caused by mine workings. With the longwall system of mining, the subsidence trough could be expected to have a flat bottomed profile. At Picture Butte the Bearpaw Formation is overlain by up to 100 m of soft overburden deposits. It is anticipated that these deposits will behave in a plastic manner. Consequently, the subsidence profile will be of greater lateral extent than would be expected if bedrock extended to surface, with gentle boundary slopes without rupture. It follows that the effects of differential settlement will not be so severe.

## 7.8 CONCLUSIONS

The observations and data obtained from the TMP at Kipp Mine, together with correlation of geotechnical data from that area and the limited geotechnical data from the Picture Butte area indicate the following:

a. Inseam physical characteristics and behaviour of the coal and proximate roof and floor strata at Kipp indicate that with proper selection and application of today's coal mining technology, a **longwall system of mining is possible at Picture Butte.**

b. **Main entries** required for the long term should be driven as small as practicable and supported by arches complemented by roof bolts where required. The preferred direction of main entry driveage is south to north or north to south - the "weak roof" direction.

c. **Service roadways for longwall retreat** required for a short-term should be driven as narrow as possible, and rectangular in shape, in an east to west or west to east direction - the "good roof" direction. Roof bolts adjacent to the ribs of the retreat pillar of coal to be mined should be angled over the rib to help prevent roof fractures parallelling the rib line at or near the face, thereby reducing rock dilution of the coal.

d. **Service roadways for longwall advance** must be of the arch type, supported by rigid or yielding arches, these would also be driven in the "good roof" direction. Roadside packs of hardwood, anhydrite or aqua-packs can provide adequate roadway stability. If legislation permits, shearers capable of cutting roadway arch profiles could be used to drive these service roadways in line with the advance of the longwall face.

e. Methane was detected only in small quantities at Kipp and therefore the same condition is expected at Picture Butte.

f. When all relevant parameters to mine design are evaluated, it is possible that some areas of the Picture Butte property will not be capable of being mined using the longwall system. Alternate mining systems may have to be considered to maximize the recovery of coal resources in areas of thin rock overburden and irregular fault bounded blocks.

POOR

QUALITY

ORIGINAL